SR 108 MP 8.89 McDonald Creek: Preliminary Hydraulic Design Report

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SR 108 McDonald Creek – Remove Fish Barrier
MP 8.89 McDonald Creek
Preliminary Hydraulic Design Report
July 2020

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Contents

Figures

Tables

1.0 Introduction and Purpose

To comply with United States, et al vs. Washington, et al No. C70-9213 Subproceeding No. 01-1 dated March 29, 2013 (a federal permanent injunction requiring the State of Washington to correct fish barriers in Water Resource Inventory Areas (WRIAs) 1-23), the Washington State Department of Transportation (WSDOT) is proposing a project to provide fish passage at the SR 108 crossing of McDonald Creek at Mile Post (MP) 8.89. This existing structure on SR 108 has been identified as a fish barrier by Washington Department of Fish and Wildlife (WDFW) and WSDOT Environmental Services Office (ESO) (Site ID 990278) due to a deficient and failed fishway that has become a chronic maintenance problem due to downstream aggradation. Per the injunction, and in order of preference, fish passage should be achieved by (a) avoiding the necessity for the roadway to cross the stream, (b) use of a full span bridge, or (c) use of the stream simulation methodology. WSDOT evaluated design options as defined in the injunction. Avoidance of the stream crossing was determined to not be viable given the location of the highway and the need to maintain this critical transportation corridor. WSDOT is proposing to replace the existing crossing structure with a structure designed using the bridge design methodology.

The structure is located in Mason County approximately 3 miles southwest of Kamilche, WA in Water Resource Inventory Area (WRIA) 14.0023. The highway runs east-west at this location and is about 1,600 feet from the confluence with Skookum Creek. McDonald Creek generally flows south to north beginning roughly 1.25 miles upstream of the SR 108 crossing. See Figure 1 for the vicinity map.

The proposed project will replace the existing sheet pile and concrete fishway and 63 feet long 4’H x 6’W concrete box culvert with a minimum 18 foot span structure to improve fish passage while providing a safe roadway for the traveling public. This proposed structure is designed to meet the requirements of the federal injunction utilizing the bridge design criteria outlined in the 2013 WDFW Water Crossing Design Guidelines (WCDG).

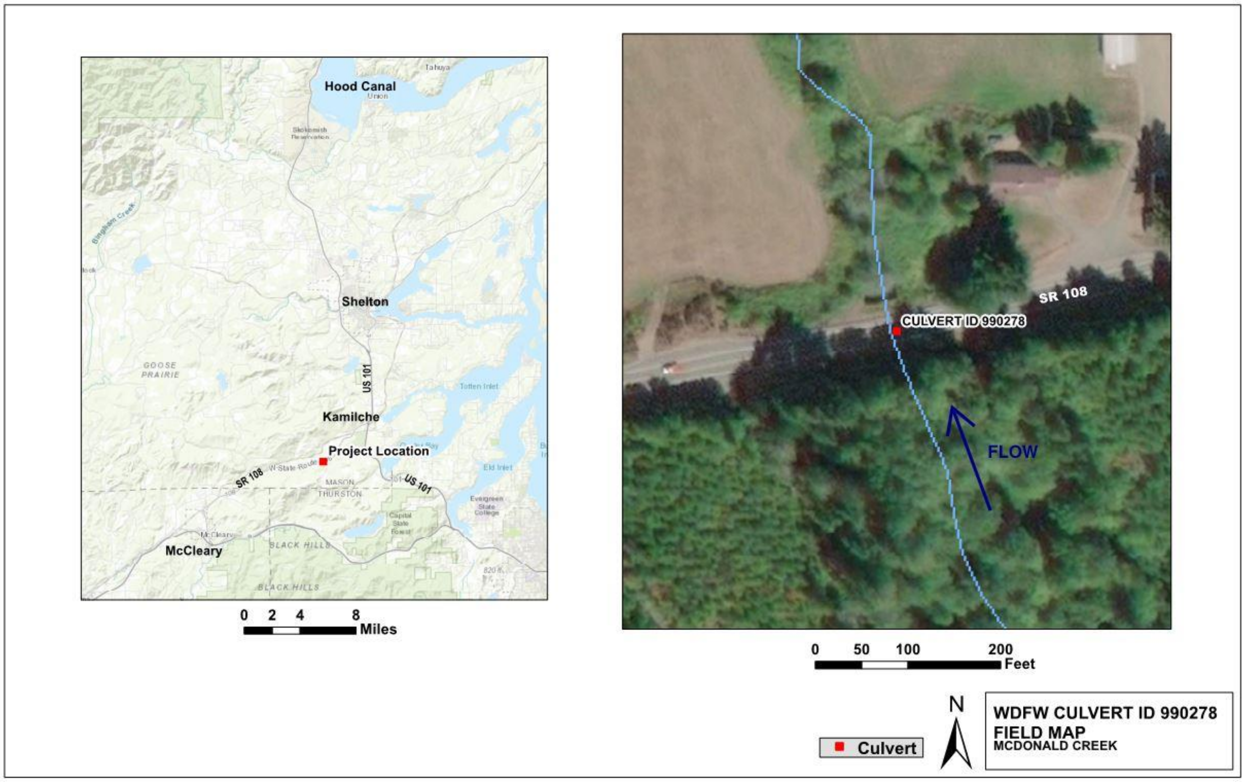

Figure 1 Vicinity map

2.0 Site Assessment

Osborn Consulting Inc. (OCI) conducted an independent site visit with HDR on August 23, 2019, to measure bankfull width, walk a portion of the stream, and attempt to locate a reference reach, to support the basis of design for the McDonald Creek at the SR 108 culvert crossing. A second independent site visit was conducted on August 29, 2019 to perform pebble counts, and supplement prior field efforts. The team walked the stream from approximately 300 feet upstream of the inlet to approximately 300 feet downstream of the outlet of the existing 4'H x 6'W concrete box culvert. The following provides a description of field observations moving from upstream to downstream.

Beginning upstream of the culvert crossing the stream flows through a reach densely vegetated with large trees and shrubs. The upstream reach is composed of pool and riffle sections throughout the channel (shown in Figure 2). Upstream bank heights ranged between 1 to 3 feet with stream benches present throughout the reach. The stream bed sediment was observed to be poorly-sorted and composed of small gravels and cobbles. Significant wood accumulations were observed throughout the upstream reach, and strong potential was noted for further wood recruitment. The stream banks immediately upstream of the culvert inlet are armored with riprap (shown in Figure 3). Two bankfull widths were measured within the upstream reach; the measurements were taken approximately 150 feet and 300 feet upstream of the existing culvert inlet, at 13.5 feet and 11.6 feet respectively. Two additional upstream bankfull widths were collected during the stakeholder site visit with WDFW, measuring 13.5 feet and 11.8 feet.

Figure 2 Typical upstream channel

Figure 3 Box culvert inlet

At the downstream end of the culvert is an existing 9-pool concrete fish ladder with concrete baffles and an overflow weir controlled with wooden flashboards. According to WDFW, the fish ladder (shown in Figure 4) has failed and become a chronic maintenance problem due to aggradation both within the fish ladder, and in the downstream reach. Significant streambed material was observed within both the existing culvert and fish ladder. The reach downstream of the culvert are densely vegetated with reed canarygrass, blackberry, and small trees (shown in Figure 5). Downstream of the fishway, a pool has formed at the base of the overflow weir. It is suspected that the pool was formed as a result of overtopping of the overflow weir. The channel narrows and becomes incised downstream of the pool, and forms a reach densely vegetated with reed canarygrass. Significant evidence of bank erosion was noted, especially on the left bank throughout the channel downstream of the culvert crossing. Downstream bank heights are taller than upstream, ranging between 3 and 6 feet throughout the reach. The downstream channel is narrower than the upstream channel. The downstream bankfull width was measured approximately 200 feet downstream of the existing culvert at 7.5 feet wide. This downstream measurement was not used for design, but for reach descriptive purposes.

Figure 4 View of concrete fish ladder at downstream end of culvert


Figure 5 Typical downstream channel, eroded left banks shown at left

3.0 Watershed Assessment

3.1 Watershed & Landcover

McDonald Creek flows in a northerly direction and converges with Skookum Creek approximately 1,600 feet downstream of the SR 108 culvert outlet. Skookum Creek drains into the Little Skookum Inlet near Kamilche, which flows into Totten Inlet and eventually into the Puget Sound. The McDonald Creek basin drains approximately 0.81 square miles at the SR 108 crossing based on LiDAR data using ArcHydro delineation and compared to the StreamStats basin. The basin ranges from a minimum of 496 feet to a maximum of 1,130 feet in elevation. The mean annual precipitation was reported at 72.1 inches (PRISM, 2019). The majority of the upper watershed is forested. Figure 6 shows a map of the basin boundary.

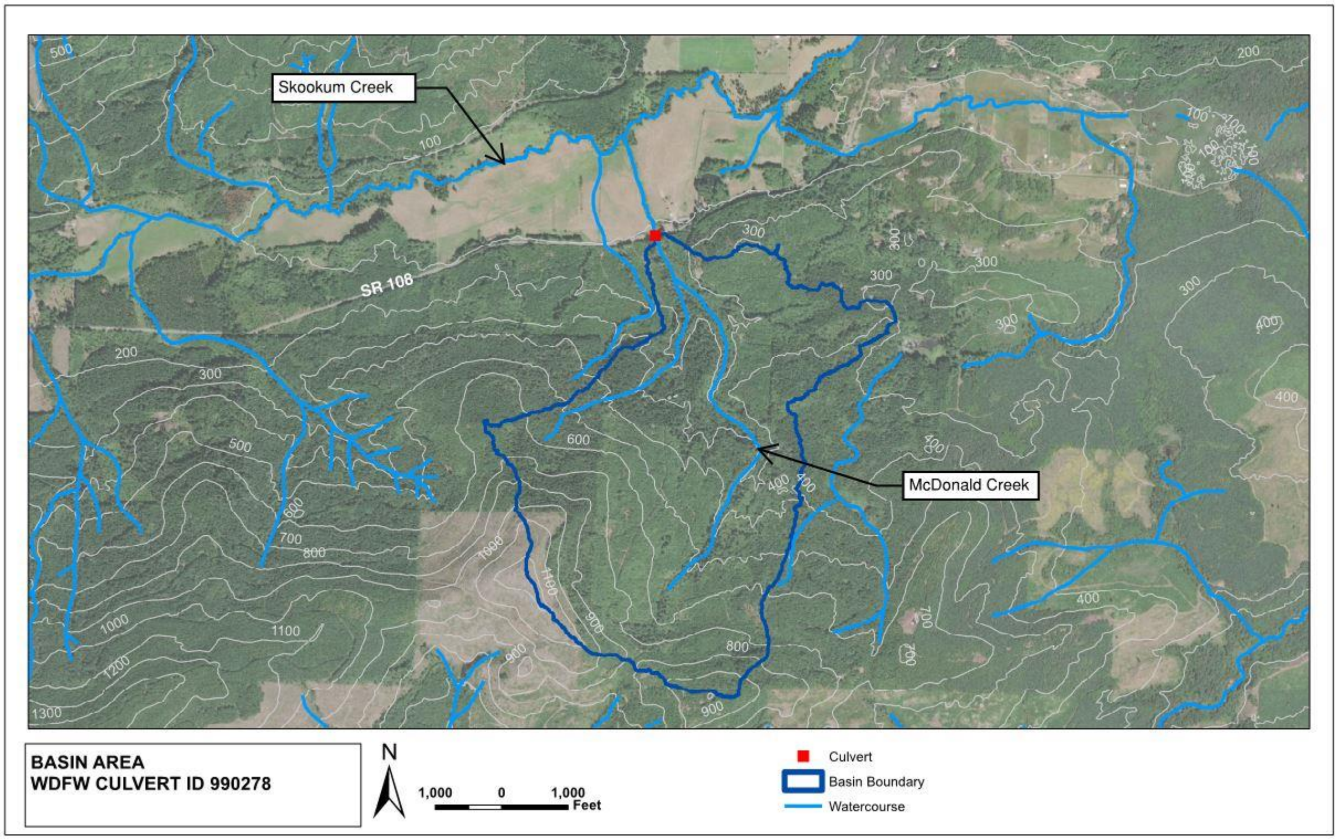

Figure 6 Basin Boundary

3.2 Mapped Floodplains

This project is not within a mapped floodplain based on the FEMA flood insurance rate map effective May 17, 1988 (shown in Figure 7). Approximately 1,275 feet downstream of the crossing, a Zone A floodplain has been mapped for Skookum Creek.

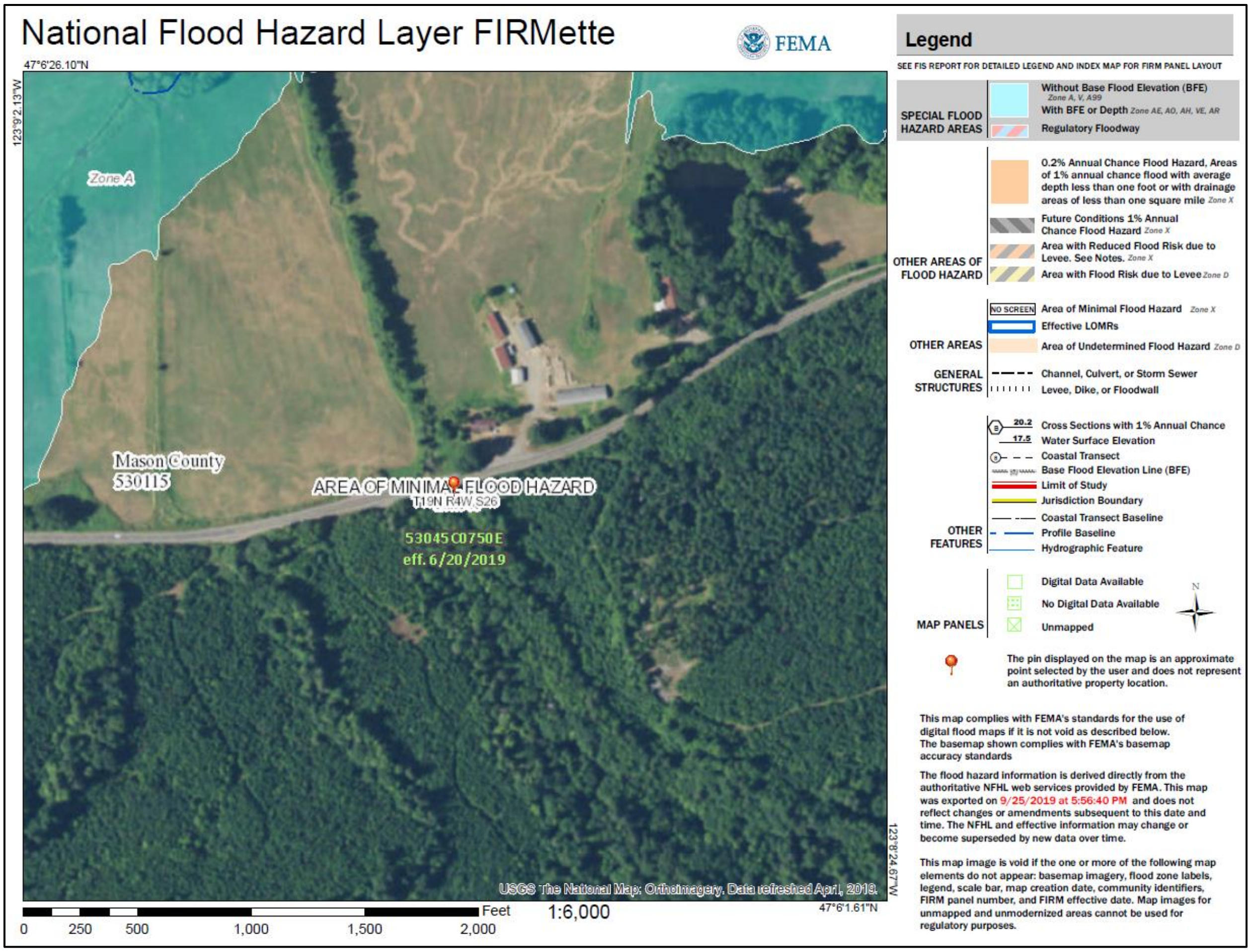

Figure 7 FEMA floodplain map (FIRM 53045C0750E)

3.3 Geology & Soils

The McDonald Creek Basin (shown in Figure 8) is underlain by deposits left by the most recent continental glacial recession event between 13,000 and 18,000 years ago. DNR classifications were used to characterize the geologic units within the McDonald Creek drainage area. The upper one-third of the basin is composed of Crescent Formation basalt (Ev_c). Vashon Stade Till (Qgt) dominates the soil profile descending in elevation toward the Kamilche Valley floor and comprises approximately 44 percent of the soils in the basin. The lower reaches, approximately one-quarter of the drainage basin, consist of Vashon Stade proglacial and recessional outwash (Qgo). These geologic units are further described as follows:

> **(Ev_c) Crescent Formation basalt** – Tertiary igneous rock of lower to middle Eocene period; characterized by dark gray greenish tint, brown where weathered, reddish and variegated along altered contact zones.
>
> **(Qgt) Till, late Wisconsinan (Pleistocene epoch), Vashon Stade -** Continental glacial deposits of Fraser Glaciation; unsorted, unstratified, highly compacted mixture of clay, silt, sand, gravel, and boulders deposited by glacial ice; typically gray and may contain interbedded stratified sand, silt, and gravel.

(Qgo) Proglacial and recessional outwash, late Wisconsinan (Pleistocene epoch), Vashon Stade - Continental glacial deposits of Fraser Glaciation; poorly to moderately sorted, rounded gravel and sand with localized coarser- and finer-grained constituents; typically shades of gray where fresh or brown where stained.

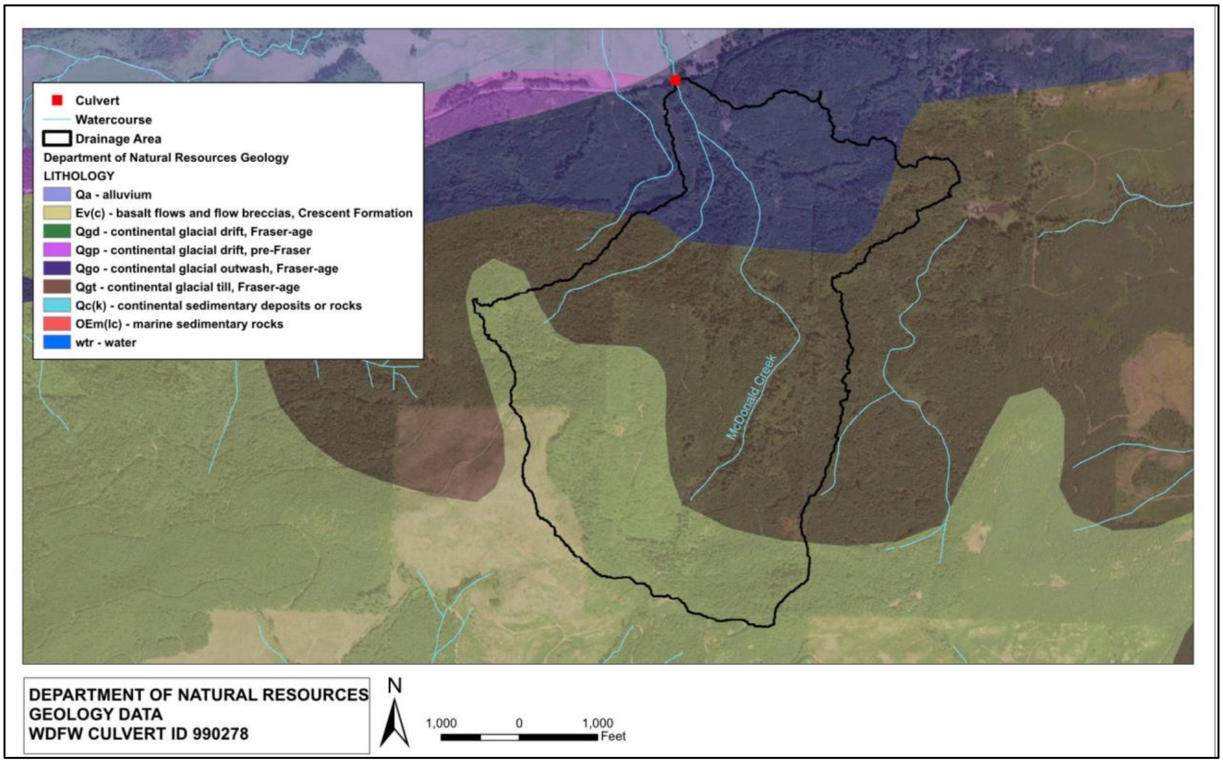

Figure 8 Geologic Map for McDonald Creek Basin (WA DNR Geologic Units 100k)

Soils units (shown in Figure 9 and Figure 10) within the basin primarily include gravelly loam, gravelly sandy loam, loam, unweathered bedrock, Tebo soil material, and Tebo-Shelton complex. Tebo soil material is described as till derived from basalt consisting of silt loam and gravelly clay loam on steep slopes. Shelton soil material is described as basal till with volcanic ash consisting of very gravelly medial loam to very gravelly sandy loam. The hydrologic soil groups (HSG) of the soils within the basin are approximately 35% A, 13% B, 1% C, and 51% of the soils are classified as “Rough mountainous land, Tebo soil material” (National Resources Conservation Service (NRCS) Web Soil Survey) and are without a hydrologic soil group, though they can be presumed to be nearly impermeable, similar to a saturated soil. These soils range from well-drained with high infiltration rates (HSG A) to unweathered bedrock with little to no capacity for infiltration or storage.

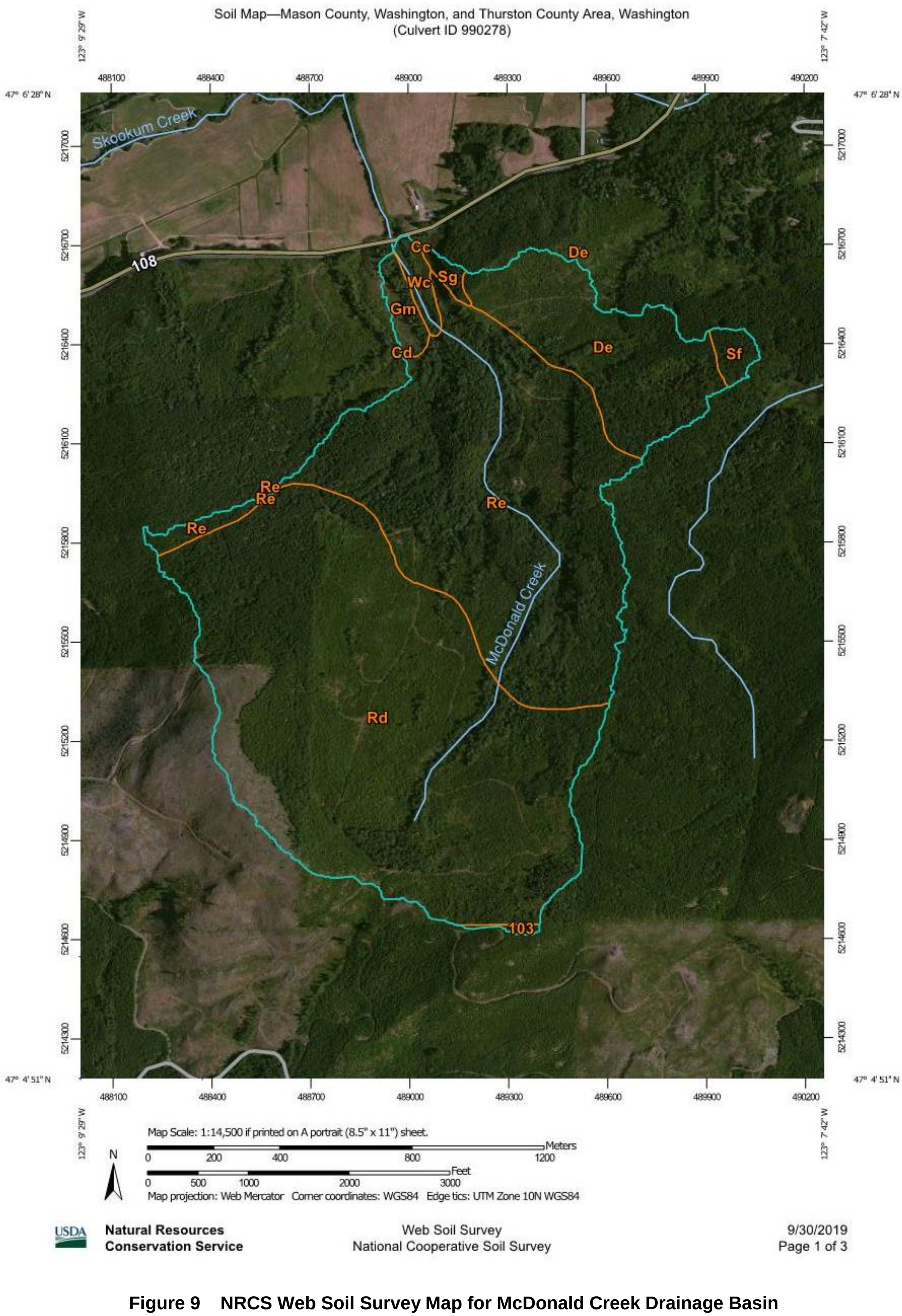

Figure 9 NRCS Web Soil Survey Map for McDonald Creek Drainage Basin

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
Cc	Cloquallum silt loam, 5 to 15 percent slopes	0.1	0.0%
Cd	Cloquallum silt loam, 15 to 30 percent slopes	0.0	0.0%
De	Delphi gravelly loam, 5 to 15 percent slopes	56.4	10.9%
Gm	Grove gravelly sandy loam, 15 to 30 percent slopes	6.1	1.2%
Rd	Rough mountainous land, Tebo soil material	263.5	50.7%
Re	Rough mountainous land, Tebo-Shelton complex	180.6	34.8%
Sf	Shelton gravelly sandy loam, 5 to 15 percent slopes	4.4	0.8%
Sg	Shelton gravelly sandy loam, 15 to 30 percent slopes	2.5	0.5%
Wc	Wadell loam, 0 to 5 percent slopes	4.9	0.9%
Subtotals for Soil Survey Area		**518.4**	**99.8%**
Totals for Area of Interest		**519.3**	**100.0%**

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
103	Schneider very gravelly loam, 40 to 65 percent slopes	0.9	0.2%
Subtotals for Soil Survey Area		**0.9**	**0.2%**
Totals for Area of Interest		**519.3**	**100.0%**

Figure 10 NRCS Web Soil Survey Map Legend for McDonald Creek Drainage Basin

McDonald Creek drains a moderately steep basin before it reaches the edge of the Skookum Creek floodplain on the north side of SR 108. Of the 0.81 square mile area that McDonald Creek drains upstream of the SR 108 crossing, the mean basin slope is 22.1 percent as reported by StreamStats. Approximately 24.3 percent of the basin area has a slope steeper than 30 percent. The basin elevations range from 496 feet at the SR 108 culvert crossing to 1,130 feet at the south and southwest edges of the drainage basin (StreamStats).

3.4 Geomorphology

3.4.1 Channel Geometry

Channel bed features include pool and riffle sections throughout the observed stream length upstream of the culvert inlet. In the downstream reach, a pool has formed below the fish ladder. The pool is likely caused by higher flows overtopping the weir and scouring the channel area below the weir. Beyond the pool, the channel was observed to be narrow and deeply incised with depth of incision approximately 6 feet (Figure 11).

Figure 11 Channel upstream of existing crossing (left) and channel downstream of existing crossing (right)

The stream channel is wider in the upstream of the SR 108 culvert crossing than in the downstream reach downstream; upstream bankfull widths measured approximately 150 and 300 feet upstream of the crossing ranged between 13.5 feet and 11.6 feet, and the downstream bankfull width measured approximately 200 feet downstream of the crossing was about 7.5 feet wide. Bank heights were measured to be 1 to 3 feet with stream benches apparent throughout the upstream channel, and bank heights were measured to be 3 to 6 feet throughout the downstream reach, though benches were not observed. While portions of the channel along the entire observed length were incised, no evidence of floodplain entrenchment was observed.

A long channel profile was developed from the 2019 survey data and 2005 Puget Sound Lowlands LiDAR data (Figure 12). Upstream and downstream of the project area, and within the detailed survey, the average reach slope is 2 percent. The slope is not continuous because there is a large drop in elevation between the upstream and downstream side of the structure.

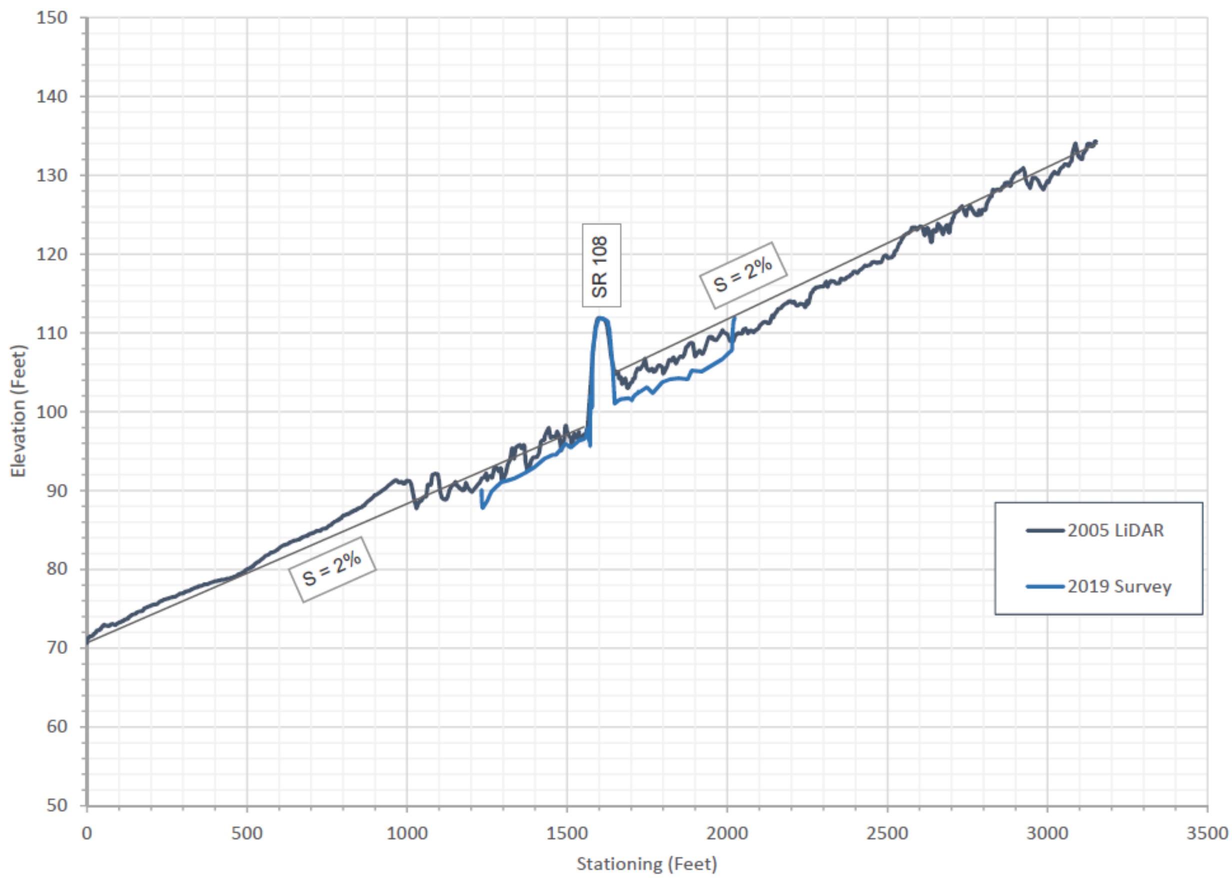

Figure 12 Long Profile

3.4.2 Potential for Aggradation, Incision and Headcutting

The channel upstream of the SR 108 culvert crossing appeared to be stable with poorly-sorted streambed sediment composed of small gravels and cobbles. The downstream reach was observed to be incised, with depth of incision ranging from 3 to 6 feet, and significant evidence of bank erosion, especially on the left bank of the stream channel. WDFW and WSDOT stated during the stakeholder site visit that the reach downstream of fish ladder has aggraded and degraded throughout the years and varied by several feet.

A longitudinal profile from the approximately 300 feet downstream to 300 feet upstream of the existing culvert does not indicate a headcut or other discontinuity in the channel grade except for at the culvert outlet. There is a fishway at the downstream end of the existing crossing that connects the culvert and the downstream channel. The culvert outlet is approximately 5 feet higher than the downstream channel, so removal of the fishway and replacement of the culvert may provide an opportunity for a headcut to develop in the downstream reach. WDFW noted this site has a history of changing channel bed elevations downstream of the culvert by several feet. The downstream reach has been observed during some years with a higher bed elevation and signs of significant aggradation.

3.4.3 Floodplain Flow Paths

The McDonald Creek/SR 108 culvert crossing project is not within a mapped floodplain as previously discussed in Section 3.2.

Upstream of the SR 108 crossing, the stream channel is wider than the downstream reach. The stream channel has a wide bottom, bank heights varied from 1 to 3 feet, and benches were observed along the channel, where flows appear to access to the floodplain. Downstream of the SR 108 crossing, McDonald Creek is highly confined and has minimal access to its floodplains. Throughout the majority of the downstream reach, the channel was confined with steep, near-vertical banks, and appeared to not to have defined floodplains.

3.4.4 Channel Migration

The channel is not expected to expand nor move around within its floodplain. The dense vegetation lining the stream banks throughout the observed reach and channel incision suggests the stream has low potential to migrate within its floodplain. The primary landcover in the watershed is forested and flows are not expected to change significantly if the land cover remains undisturbed.

3.4.5 Existing LWM and Potential for Recruitment

In the upstream reach, significant wood accumulations were observed and a strong potential for further wood recruitment throughout the reach was noted. The upstream reach appears to have adequate depth and channel width to transport LWM from upstream reaches. Existing riparian forest consisted of a mixture of large deciduous and coniferous trees upstream of the SR 108 crossings.

The riparian area in the downstream reach was observed to be heavily vegetated with reed canarygrass, blackberry, and small coniferous trees. Several wood accumulations were observed within the downstream reach, with moderate recruitment potential due to bank erosion. The downstream reach of McDonald Creek does not appear to have adequate channel width to transport LWM from upstream reaches. Therefore, all potential for LWM recruitment is from localized recruitment such as deadfall, windfall, and bank erosion. Streambed boulders were not observed within the limits of the site visit for this stream.

3.4.6 Sediment Size Distribution

The streambed substrate upstream of the culvert inlet is dominated by fine silt and sand material with minimal gravel and cobbles present. Generally, the streambed sediment in the upstream reach, including the identified reference reach location is well-sorted, and is composed of small gravels and cobbles. Downstream, the streambed substrate contains more small gravels and cobbles. One set of pebble counts was performed on the upstream side of the culvert crossing, within the identified reference reach location. The results of the sediment size distribution are compiled in the graph (Figure 13) and Table 1 below. Figure 14 includes pictures of the performed pebble count.

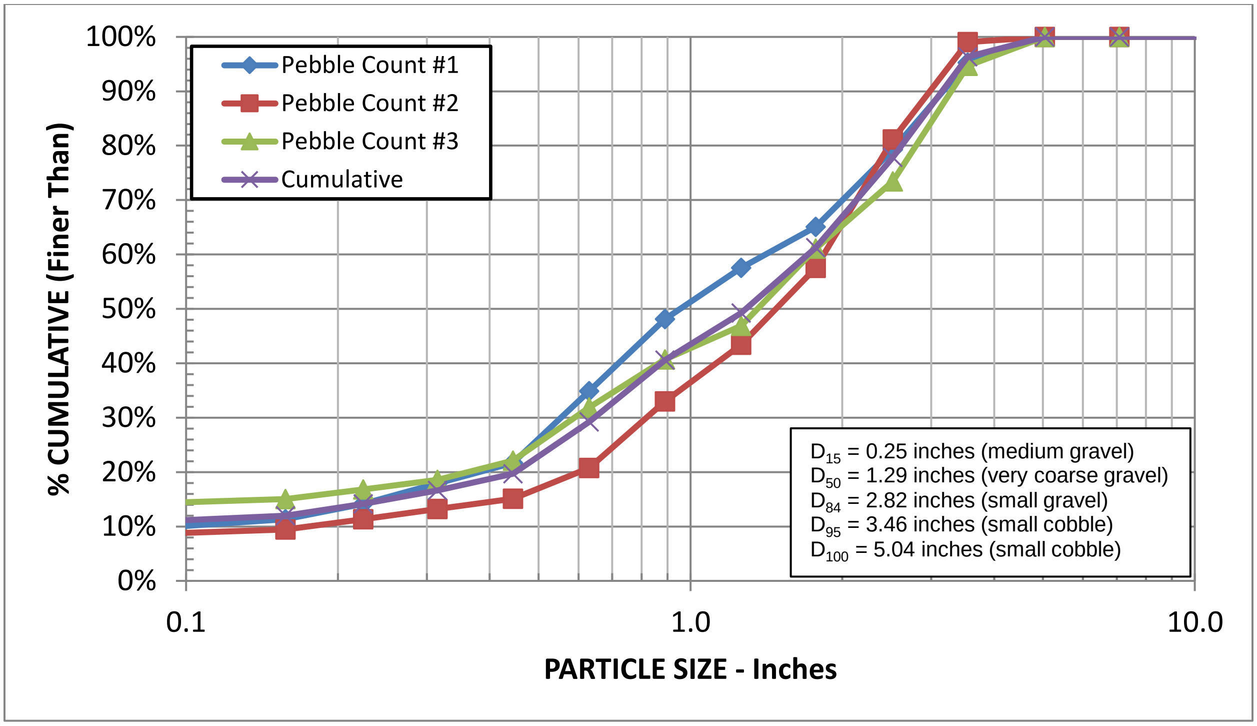

Figure 13 Sediment size distribution

Table 1 Sediment properties downstream of SR 108 Crossing

Particle	Diameter (in)
D_{15}	0.25
D_{35}	0.75
D_{50}	1.29
D_{84}	2.82
D_{95}	3.46
D_{100}	5.04

Figure 14 Pebble counts in the upstream reach

3.5 Groundwater

The Washington State Department of Ecology well log database, EIM database, and the USGS NWIS were queried for groundwater level data. One water well (Well Report ID 251978) was identified approximately 360 feet east of the channel and 550 feet downstream of the crossing. It appears that the well installed in 2000 is for domestic use and serves the residential property. The static water level was found to be 31 feet below the top of the well.

No obvious signs that groundwater might be close to the surface other than the flow in the channel were observed during the site visit in August 2019.

4.0 Fish Resources and Site Habitat Assessment

4.1 Fish Use

Skookum Creek and its tributaries, including the portion of McDonald Creek that is located in the project site, support the occurrence of fall-run coho salmon (*Oncorhynchus kisutch*), chum salmon (*Oncorhynchus keta*), winter-run steelhead (*Oncorhynchus mykiss*) and coastal cutthroat trout (*Oncorhynchus clarkii clarkii*) (WDFW PHS data 2019a; WDFW Salmonscape 2019b; Streamnet 2019). Of these species, winter steelhead that inhabit the watershed are part of the Puget Sound Distinct Population Segment (DPS) and are federally listed as threatened under the Endangered Species Act (ESA) of 1973. Besides salmonids, several additional fish species, including sculpin and lamprey, also inhabit the watershed. Table 2 provides a list of native fish potentially found in Skookum Creek and its tributaries. There was very little water in the stream channel during the time of the site visit in August, 2019, and no fish were observed.

Table 2 Native fish species potentially found

Species	Source (Assumed, Mapped, or Documented)	Pre-Existing Fish Use Surveys (spawner surveys or other biological observations)	Life History Present (Egg, Juvenile, Adult)	Limiting Habitat Factors	Stock Status and/or ESA Listing
Coho (*Onchorhynchus kisutch*)	Documented	Statewide Integrated Fish Distribution (SwIFD), Salmonscape, PHS	Egg, Juvenile, Adult	Spawning and Rearing	Not Warranted
Fall Chum (*Onchorhynchus keta*)	Documented	SwIFD, Salmonscape, PHS	Egg, Juvenile, Adult	Spawning and Rearing	Not Warranted
Winter Steelhead (*Onchoryhnchus mykiss*)	Documented	SwIFD, Salmonscape, PHS	Juvenile, Adult	Spawning and Rearing	Federally Threatened
Coastal Cutthroat (*Onchoryhnchus clarkii clarkii*)	Documented	SwIFD, Salmonscape, PHS	Egg, Juvenile, Adult	Spawning and Rearing	Not Warranted
Sculpin (*Cottus*)	Assumed	None	Egg, Juvenile, Adult	Spawning and Rearing	Not Warranted
Lamprey (*Lampreta*)	Assumed	None	Egg, Juvenile, Adult	Spawning and Rearing	Not Warranted

4.2 Existing Habitat

Skookum Creek is a significant watershed in South Puget Sound, with numerous tributaries providing habitat for salmonids. Land use at higher elevations is predominately timber production, with livestock and pasture/hayfields in the mid and lower valleys. The Skookum Creek watershed provides spawning and rearing habitat for coho, chum, steelhead, and cutthroat trout throughout the mainstem and accessible reaches of its tributaries. These anadromous species are part of Puget Sound stocks and access Skookum Creek through the Little Skookum Inlet off Totten Inlet in South Puget Sound.

In addition to fish passage barriers in the upper watershed, the most significant biological impairments are habitat diversity and quantity, sediment load and transport, and summer water temperatures. McDonald Creek is a right bank tributary to Skookum Creek that provides rearing and migratory habitat, as well as potential spawning habitat for salmonids and other fish species.

4.2.1 Immediate Crossing

The current crossing is a concrete box culvert and fishway that has become impassable at low flows due to sediment deposition. The fishway and culvert was reported as 33% passable by a WDFW assessment in 2015. Coho, chum, and steelhead are not known to migrate above the culvert during low flows. During seasonal high flows, upstream passage is possible. During November of 2018, WSDOT staff observed chum immediately upstream of the crossing. The barrier condition of the culvert is assumed to be impeding both adult and juvenile salmon use of reaches upstream.

4.2.2 Quality Within Reach

Downstream of the SR 108 culvert and fishway, McDonald Creek flows through a narrow riparian corridor of alders (*Alnus rubra*) and willows (*Salix spp.*), with open areas of reed canarygrass (*Phalaris arundinacea*). Just downstream of the fishway, the channel becomes choked by reed canarygrass for a short section, before it flows through the narrow alder and willow corridor that bisects hay fields. The stream channel is shaded by a riparian corridor, mature forest cover and large woody material (LWM) recruitment are much more abundant in the upstream study reach. Habitat in this reach is suited to migration, with limited rearing habitat during higher seasonal flows. The substrate is dominated by gravel and fines. Spawning habitat is not present in the downstream study reach, but is potentially present further downstream. Downstream of the study reach, the stream flows through a forested area and joins Skookum Creek. WDFW reported chum carcasses observed in the lower reaches of the creek in 2015 (WDFW fish passage report 990278).

The distance from the crossing to the confluence with Skookum Creek is approximately 0.3 river miles. Skookum Creek continues for approximately 2.6 miles to where it enters Little Skookum Inlet, and on to Totten Inlet off Puget Sound.

Upstream of the SR 108 crossing, McDonald Creek flows through a mature mixed forested area comprised primarily of fir (*Pseudotsuga menziesii*), alder, and big leaf maple (*Acer macrophyllum*), with some large cedars (*Thuja plicata*). The banks and understory are dominated by ferns with native and non-native shrub species including salmonberry (*Rubus spectabilis*), willows (Salix spp.), vine maple (*Acer circinatum*), and Himalayan blackberry (*Rubus armeniacus*). The mature forest and shrub cover provides good shading, nutrient inputs, and LWM recruitment.

The stream channel in the upstream reach had a small amount of flow at the time of the site visit in August 2019, and is predominantly riffle habitat with gravel and some cobble in the substrate. Gravel bars were present near the banks at meanders throughout the reach. This reach potentially provides good rearing and spawning habitat, although large pools are lacking.

4.2.3 Length of Potential Gain

In December of 2015, WDFW surveyed 3.67 miles (19,387 feet) of the McDonald Creek upstream of the project site. Two upstream culvert crossings have been restored to passable condition, contributing to the habitat gain. The upstream surveyed reach was documented as providing 1.4 acres of potential spawning habitat, and 2.0 acres of rearing habitat (WDFW report 990278).

4.2.4 Other Barriers in System

Currently there is a single mapped passage barrier upstream of the project reach in McDonald Creek, high up in the basin at a culvert crossing under a forest road (site ID 115 MC301). The WDFW survey report from 2015 for this crossing lists it as a complete barrier due to a drop at the culvert outlet.

Downstream of the crossing under SR 108, McDonald Creek flows roughly northward for approximately 0.3 miles, and enters the right bank of Skookum Creek. There are no barriers mapped downstream of the project crossing. Skookum Creek then flows roughly eastward and crosses under SR 108 and US 101 before entering Little Skookum Inlet. These crossings are bridges; there are no fish passage barriers in Skookum Creek downstream of the project crossing.

Figure 15 presents a map of McDonald Creek where it joins Skookum Creek north of the project culvert, as well as the fish passage features that were documented by WDFW during their fish passage inventory and habitat survey.

4.2.5 Other Restoration Efforts in System

Commercial timberlands dominate the headwaters and upper watershed, while agricultural pasturelands, rural residential and urban development make up the majority of the valley floor through the lowlands.

The Squaxin Island Tribe owns portions of land in the lower reaches of Skookum Creek and its tributaries as it runs through the reservation. The Tribe, along with conservation groups have several completed and ongoing restoration and preservation projects in the Skookum Creek watershed. Tribal restoration projects in the watershed have improved freshwater habitat for salmonids, particularly for the coho run. Where Skookum Creek runs through Tribal property, the Squaxin Island Tribe has set aside 150-foot buffers on each side of the creek to protect ecological functions, and has begun replanting efforts.

The Tribe has also worked with the South Puget Sound Salmon Enhancement Group to dig out the steep, eroded banks of the lower creek. Instead of the near vertical 10-foot wall that previously existed, the streambank is now a gentle slope and creates floodplain connectivity. Additionally, the partners are building logjams to recreate natural conditions of in-stream habitat to help create pools where adult salmon can rest while migrating upstream and rearing juveniles can find refuge.

Work has been undertaken to place additional wood in the tributaries, with substantial LWM and key pieces being added to Reitdorf Creek, a left-bank tributary to Skookum Creek, in 2002 with the use of helicopters. McDonald Creek has also received two Family Forest Fish Passage Program projects, each removing previous partial barriers upstream of the SR 108 crossing.

The Washington Wildlife and Recreation Coalition is working in partnership with the Squaxin Island Tribe to help acquire and permanently protect 158 acres of wetlands and shorelines along Skookum Creek, using grant funding for the Skookum Valley Wetland Acquisition. The Squaxin Island Tribe’s plans to buy up to 614 acres in the Skookum Valley, depending on landowners’ willingness. This project will protect more than 4 miles of Skookum Creek and an additional 4.4 miles of tributaries, as well as a number of wetlands, stream banks, and forests. Fish passage features can be seen in Figure 15 below.

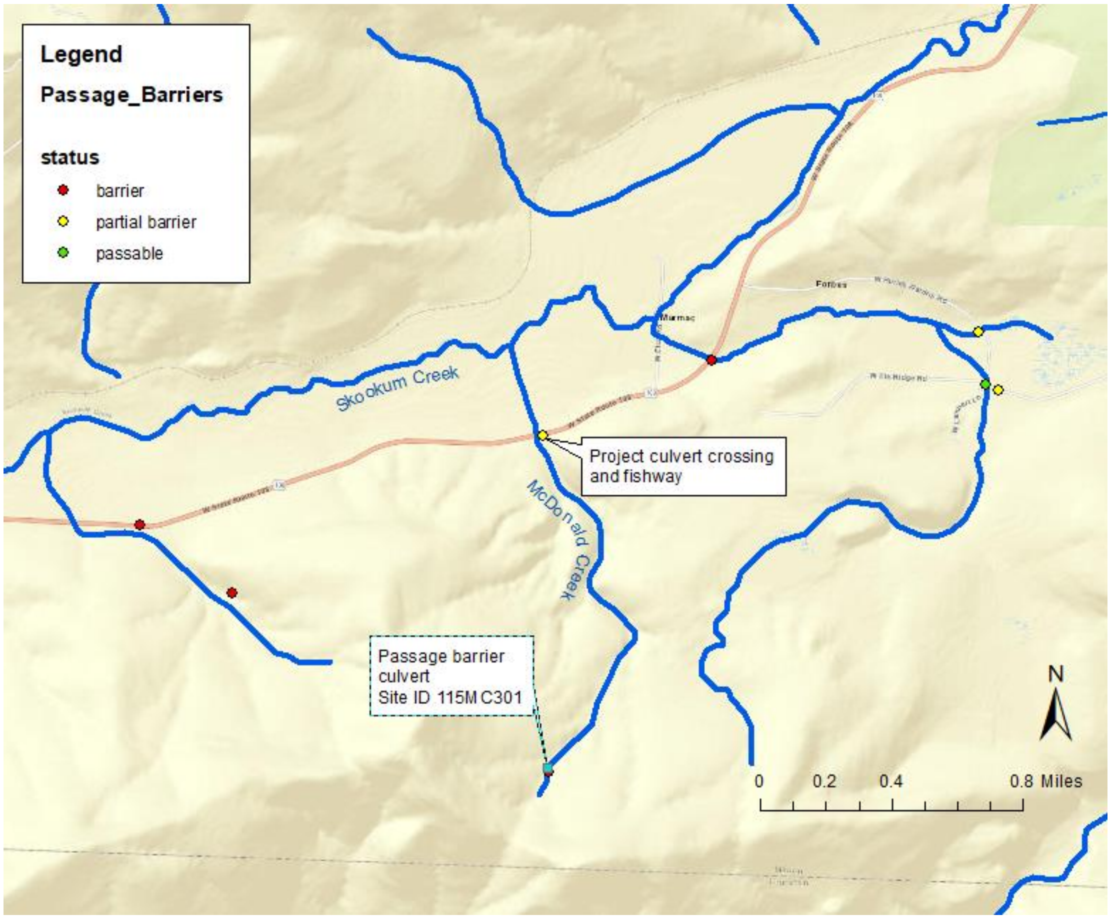

Figure 15 Fish passage features located on McDonald Creek

5.0 Reference Reach Selection

During the August 23, 2019, site visit, the field team walked approximately 300 feet upstream and 300 feet downstream of the McDonald Creek culvert crossing at SR 108. A reference reach (shown in Figure 16) was identified between the bankfull width 1 (BFW 1) and the bankfull width 2 (BFW 2) measurement locations. This area is considered to be representative of the natural channel condition for planned design of the culvert crossing. The desktop-estimated stream gradient at the location of the reference reach is approximately 3%.

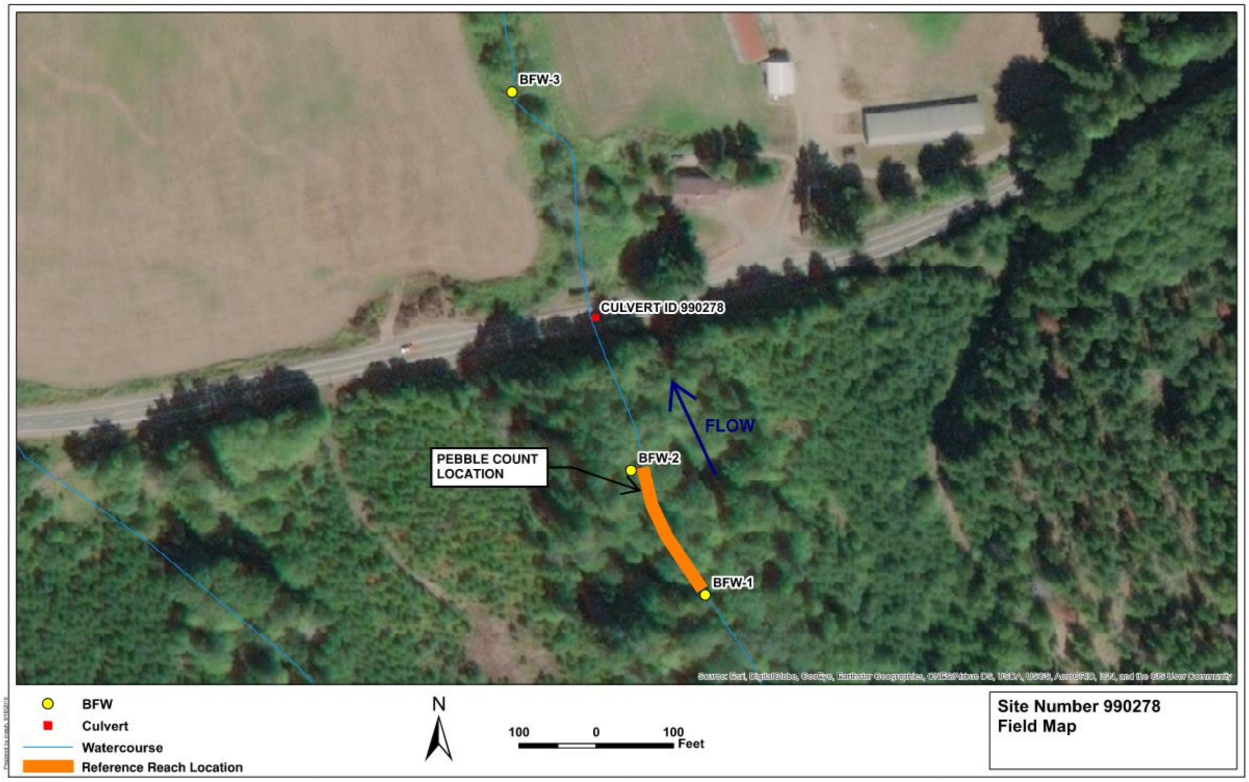

Figure 16 Bankfull width, pebble count and reference reach locations

Two bankfull widths were collected during the August 23, 2019 site visit (Figure 17). The first, BFW 1, was measured as 11.6 feet, the second, BFW 2, was measured as 13.5 feet. During the stakeholder site visit WDFW agreed to use three upstream bankfull width measurements, 13.5 feet, 13.5 feet, and 11. 8 feet. The first 13.5 feet was from the previously measured BFW 2, and the two new measurements were collected upstream of BFW 2. The average of these three measurements was rounded up to an agreed upon design bankfull width of 13 feet. Bank heights in the reference reach section range between 1 to 3 feet high. Generally, the streambed sediment in the reference reach was observed to poorly-sorted and composed of small gravels and cobbles. Pebble counts were conducted in the reference reach section and the results are summarized above in Section 3.4.6. Additionally, the reference reach contained significant wood accumulations and strong potential for further wood recruitment throughout the length of the upstream reach.

Figure 17 Bankfull width measurements within the reference reach locations

6.0 Hydrology and Peak Flow Estimates

Due to lack of stream flow data on McDonald Creek, peak flow estimates for McDonald Creek were obtained from the USGS Regression Equation (Mastin, et al., 2016). McDonald Creek has a basin area of 0.81 square miles and a mean annual precipitation within the basin of 72.1 inches (PRISM, 2019). Table 3 shows the calculated peak flows and prediction intervals (at a 90% confidence level) for McDonald Creek at SR 108.

Table 3 Peak flows, Standard Error of Prediction and Prediction Intervals (at a 90% confidence interval) for McDonald Creek at SR 108

Mean Recurrence Interval (MRI)	McDonald Creek at SR 108 (cfs)	Standard Error of Prediction	Prediction Interval (lower)	Prediction Interval (upper)
2	43.4	43.2	21.9	86.1
5	67.4	44.4	33.2	137
10	83.3	45.6	40.6	171
25	103	48.1	48.1	221
50	118	50.5	53.5	260
100	134	51.8	59.6	302
200	149	54.2	63.8	348
500	170	57.7	69.6	415

7.0 Hydraulic Analysis

The hydraulic analysis of the existing and proposed SR 108 McDonald Creek crossing was performed using Bureau of Reclamation's SRH-2D Version 3.2.0 (USBR, 2017) computer program, a two-dimensional hydraulic and sediment transport model. It includes the ability to model dynamic interactions between the stream channel and overbanks, roadway overtopping, culverts, and the influence of bridge decks on bridge backwater. Pre- and post-processing of the model was completed using SMS Version 13.0.7 (Aquaveo, 2018). Appendix A contains detailed output from the hydraulic modeling effort.

Two scenarios were analyzed for determining stream characteristics for McDonald Creek with the SRH-2D models: 1) existing conditions with the concrete box culvert and fish ladder and 2) future conditions with the proposed 18 foot hydraulic opening.

7.1 Model Development

7.1.1 Topography

Detailed channel geometry data in the model was obtained from the MicroStation and InRoads files, which were developed from topographic surveys performed by Lin & Associate surveyors. Proposed channel geometry was developed from the proposed grading surface created by HDR Engineering, Inc.

7.1.2 Model Extent and Computational Mesh

The hydraulic model upstream and downstream extents are consistent with the detailed survey boundary, approximately 355 feet upstream of the existing culvert outlet and 300 feet downstream of the existing culvert outlet, measured along the channel centerline. The computational mesh elements was a combination of patched and paved (triangular) elements, with finer resolution in the channel and larger elements in the floodplain (Figure 18).

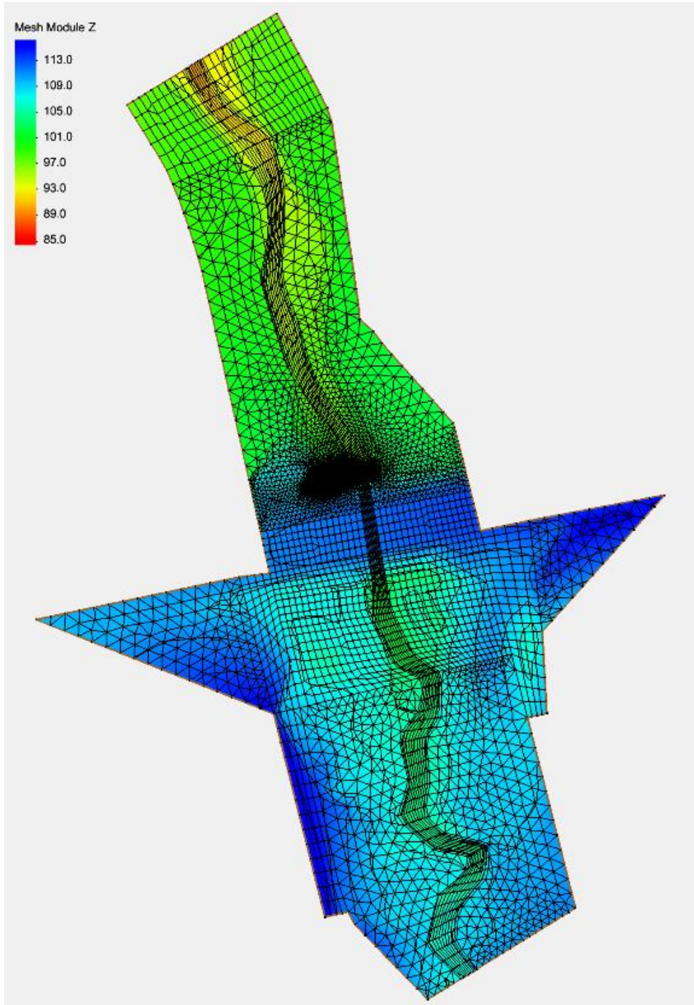

Figure 18 Existing computational mesh with underlying terrain

7.1.3 Roughness

Manning's n values were estimated based of site observations, aerial photography and standard engineering values (Chow, 1959) and are summarized below (Table 4). Aerial image was used to delineate plan form extents of vegetation coverage and pair them with field observations within the floodplains. Roughness in the overbanks represents dense vegetation and undergrowth associated with the grasses, shrubs and trees in the riparian areas.

Table 4 Summary of roughness coefficients

Land Cover	Manning's Roughness Coefficient
Channel	0.045
Roadway	0.012
Fish Ladder	0.035
Floodplain	0.1

7.1.4 Boundary Conditions

Model simulations were performed using multiple quasi-steady state discharges ranging from the 2-year to 500-year peak flow events summarized described in Section 6.0. External boundary conditions were applied at the upstream and downstream extents of the model and remained the same between the existing and proposed conditions runs. A constant flow rate was specified at the upstream external boundary condition, while a normal depth rating curve was specified at the downstream boundary. The downstream normal depth boundary condition rating curve was developed within SMS using the existing terrain, assuming a downstream slope of 4% as measured from the survey and a composite roughness of 0.045.

An HY-8 internal boundary condition was specified in the existing conditions model to represent the existing concrete box culvert. The existing crossing was modeled as a concrete box with a 6-foot (72-inch) span and 4-foot (48-inch) rise within the HY-8. A manning's roughness of 0.012 was assigned to the culvert. The culvert was assumed to be unobstructed and free from any stream material.

7.1.5 Model Geometries

Two geometries were developed for simulation with SRH-2D, representing existing and proposed conditions. The existing conditions includes the existing box culvert crossing of SR 108. The existing condition geometry was modified to develop the proposed conditions by removing the existing culvert, fish ladder, and associated internal boundary conditions. Model geometry outside of the proposed improvements are the same for the proposed conditions as the existing condition.

7.2 Model Results

Hydraulic results were summarized and compared at common locations between the existing and proposed simulations (Figure 19). The upstream cross section is located at approximate station 4+37 and is at the inlet of the proposed hydraulic opening. Downstream the cross section was located at station 2+41, 88 feet downstream of the existing culvert outlet. Hydraulic variables reported include water surface elevation, depth, velocity and shear stress averaged along the cross section. Appendix A contains the more detailed hydraulic output.

In addition to cross section results, results were summarized along the longitudinal profile. Both existing and proposed conditions use the same alignment for the purpose of reporting results (Figure 20).

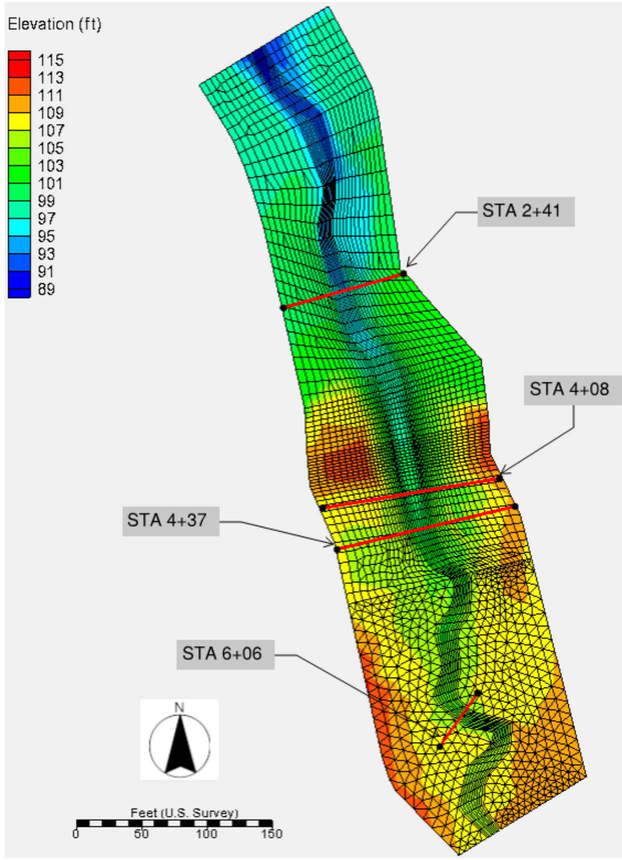

Figure 19 Locations of cross sections (on proposed mesh) used for results reporting

Figure 20 Longitudinal profile stationing for existing and proposed conditions

7.2.1 Existing conditions – Box Culvert

Existing conditions hydraulic results are summarized for the upstream and downstream cross sections in Table 5 below. Under existing conditions, the culvert causes a backwater upstream for the range of flows simulated (Figure 21). Pressure flow conditions were first observed during the 25-year event simulation. The existing roadway was not overtopped by the 500-year event. Downstream of the culvert, the water surface elevations are controlled by the existing fish ladder and weir. Downstream of the fish ladder, the slope of the channel, and the hydraulic slope increase.

As a result of the backwater, the upstream depths are greater than the downstream reach. In addition, the upstream shear and velocities are lower than their downstream counter parts. Upstream channel velocities at STA 6+06 vary from 3.59 ft/sec during the 2-year event to 4.95 ft/sec during the 50-year event. The velocities upstream decrease due to the back water effects of the pressure flow through the culvert. At the downstream cross section velocities ranged from 4.41 ft/sec at the 2-year event to 7.19 ft/sec at the 500-year event. Shear varied from 0.8 lb/ft^2 to 1.15 lb/ft^2 at the upstream cross section during the 2-year and 50-year events, respectively. Larger shear values were present in the downstream cross section, ranging from 1.42 lb/ft^2 during the 2-year event to 2.66 lb/ft^2 at the 500-year event. When looking at the entire model domain, the largest velocities occurred downstream of the culvert where the flow is constricted by the fish ladder (Figure 22).

Table 5 Hydraulic results for existing conditions within main channel

Hydraulic Parameter	Cross Section Station (STA)	2-yr	25-yr	50-yr	100-yr	500-yr
Average Water Surface Elevation (ft)	2+42	96.05	96.66	96.77	96.9	97.16
	4+37	103.18	104.79	105.16	105.64	106.92
	6+06	105.54	106.34	106.5	106.7	107.36
Max Depth (ft)	2+42	1.04	1.64	1.76	1.89	2.17
	4+37	1.75	3.37	3.74	4.22	5.51
	6+06	1.34	2.14	2.3	2.49	3.15
Average Velocity (ft/s)	2+42	4.41	5.9	6.22	6.56	7.19
	4+37	2.43	2.36	2.38	2.24	1.59
	6+06	3.59	4.79	4.95	4.98	4.31
Average Shear (lb/sq-ft)	2+42	1.42	2.07	2.24	2.38	2.66
	4+37	0.4	0.28	0.27	0.21	0.1
	6+06	0.8	1.11	1.15	1.13	0.78

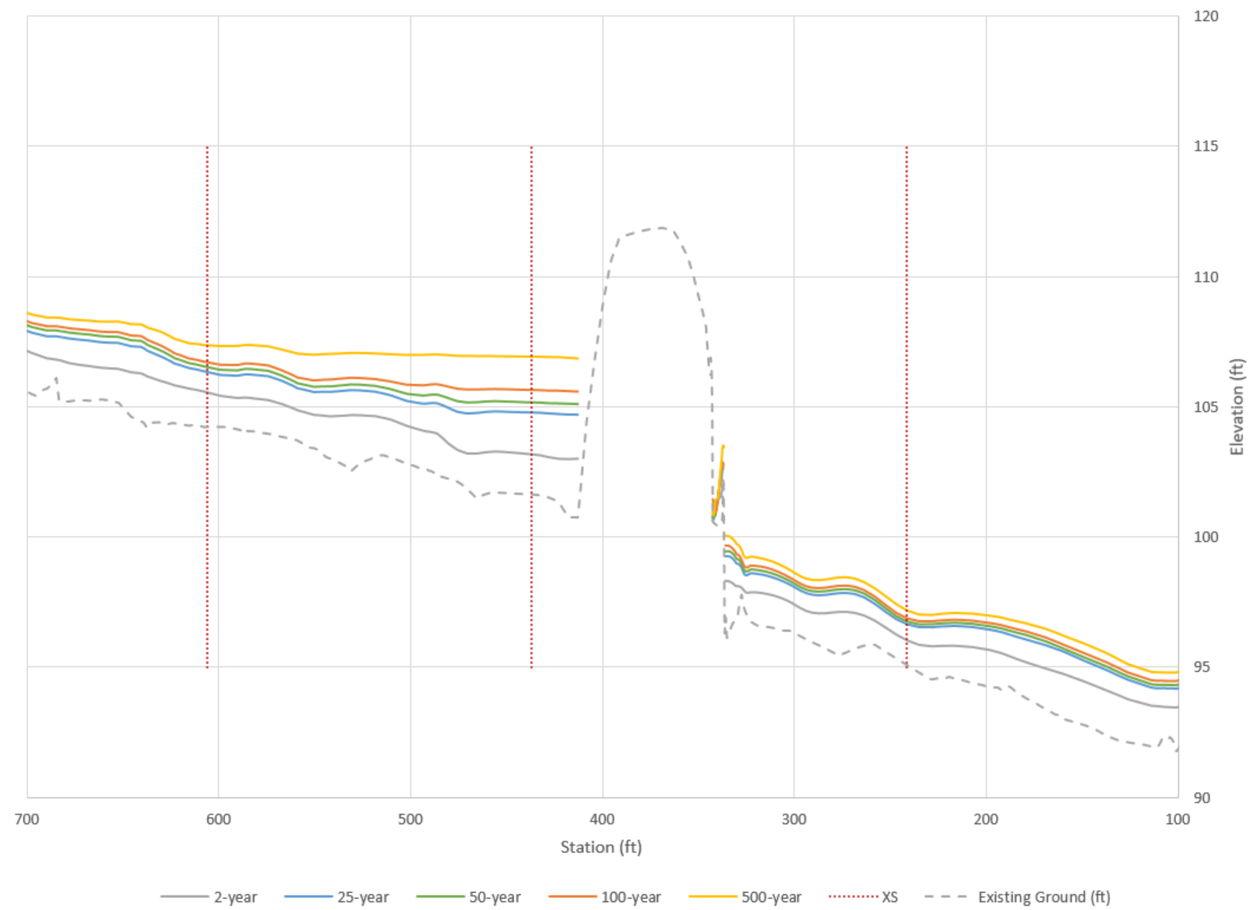

Figure 21 Existing conditions water surface profiles

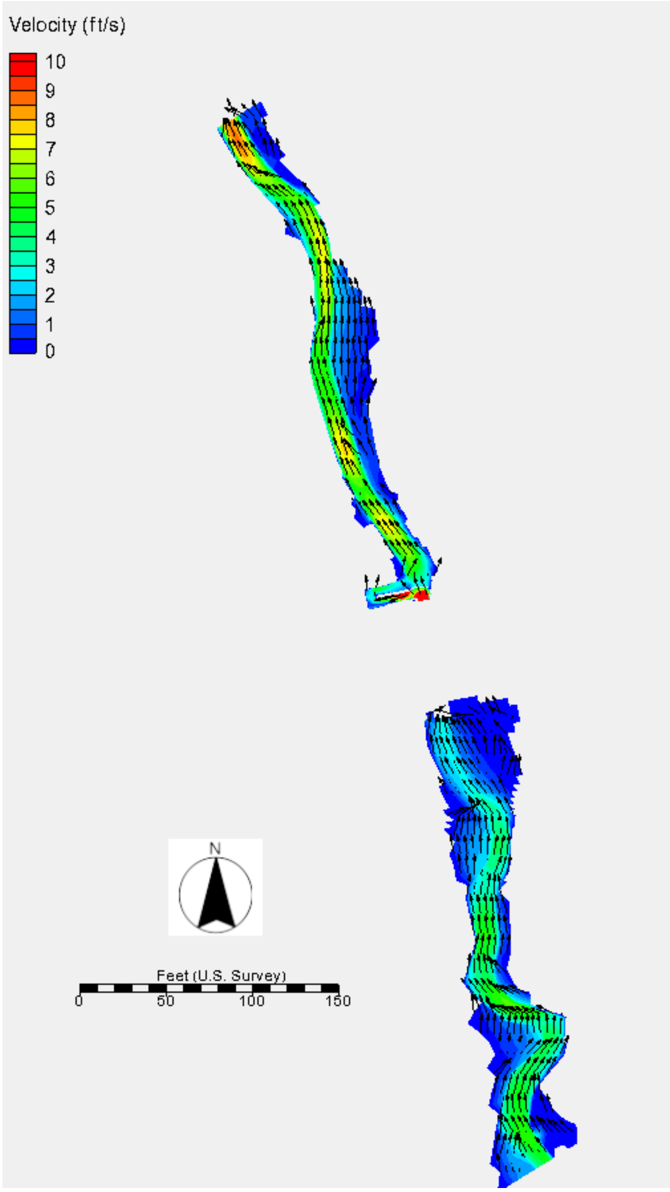

Figure 22 Existing conditions 100-year velocity map

7.2.2 Future conditions – Proposed 18 Foot Span Structure

Proposed conditions hydraulic results are summarized in Table 6. The larger proposed structure reduced water surface elevations upstream and did not result in any backwater (Figure 23). The 100-year water surface elevation upstream of the crossing was decreased by 3.30 feet when compared to existing conditions.

With the removal of the backwater condition, upstream channel velocities increased from existing conditions, varying at station 4+37 from 3.85 ft/sec during the 2-year event to 6.89 ft/sec during the 500-year event. Downstream, velocities increased compared to the existing conditions, varying from 4.7 to 7.22 ft/sec at 2 and 500-year events respectively. Similar to the velocity results, shear increased upstream of the crossing at station 4+37, varying from 1.14 lb/ft^2 to 2.48 lb/ft^2 during 2 and 500-year as well. At the downstream cross section, shear values increased from existing conditions. Velocities and shear under the proposed crossing are increased and depths decrease compared to the existing conditions model. The increases are due to the removal of hydraulic controls that backwaters the culvert and upstream reach. The fish ladder and weir worked as an energy dissipater and minimized the velocity downstream of the existing geometry (Figure 24).

Table 6 Hydraulic results for proposed conditions within main channel

Hydraulic Parameter	Cross Section Station (STA)	2-yr	25-yr	50-yr	100-yr	500-yr
Average Water Surface Elevation (ft)	2+41	96.13	96.78	96.9	97.02	97.28
	4+08	100.89	101.4	101.51	101.61	101.83
	4+37	101.59	102.1	102.2	102.31	102.52
	6+06	105.53	106.32	106.47	106.63	106.96
Max Depth (ft)	2+41	1.15	1.81	1.93	2.05	2.3
	4+08	0.99	1.51	1.62	1.72	1.94
	4+37	0.89	1.41	1.51	1.62	1.83
	6+06	1.33	2.12	2.27	2.43	2.76
Average Velocity (ft/s)	2+41	4.7	6.02	6.34	6.63	7.22
	4+08	3.85	5.47	5.81	6.14	6.83
	4+37	3.85	5.63	5.99	6.31	6.89
	6+06	3.56	4.81	4.99	5.12	5.24
Average Shear (lb/sq-ft)	2+41	1.47	2.01	2.17	2.3	2.57
	4+08	1.13	1.77	1.92	2.07	2.38
	4+37	1.14	1.88	2.04	2.18	2.48
	6+06	0.79	1.12	1.17	1.2	1.2

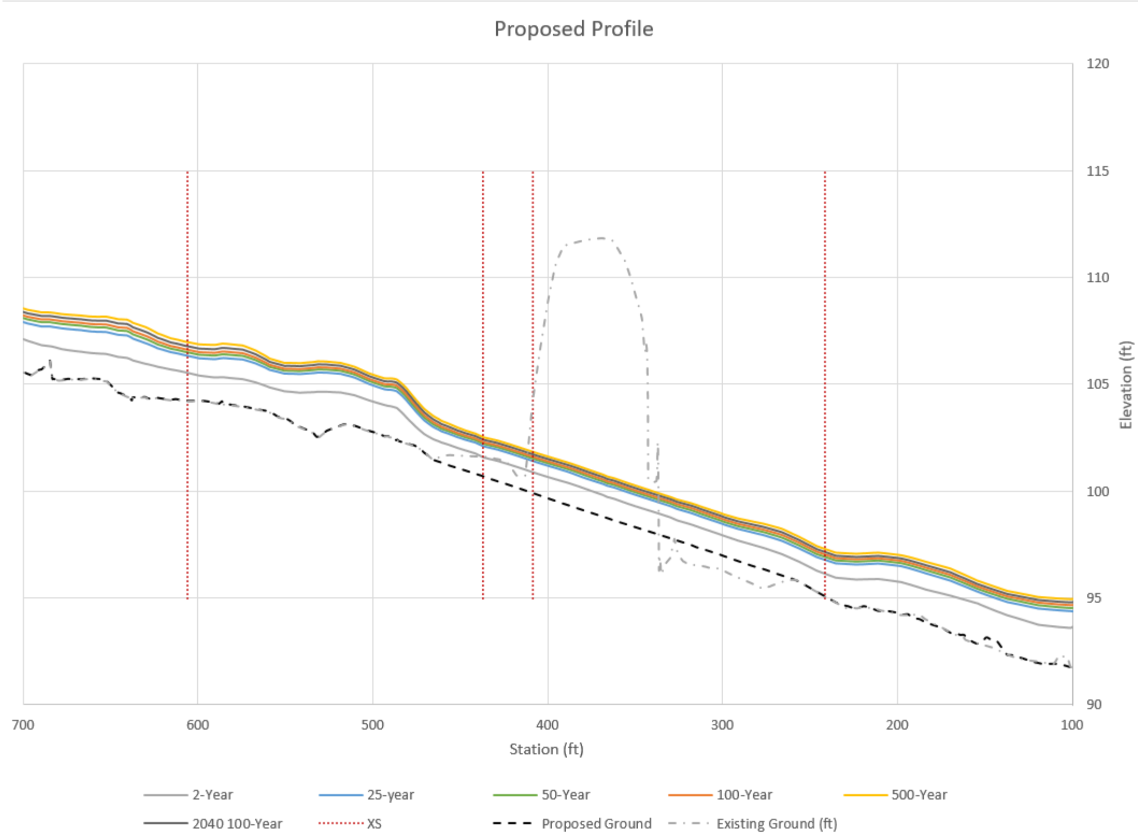

Figure 23 Proposed conditions water surface profiles

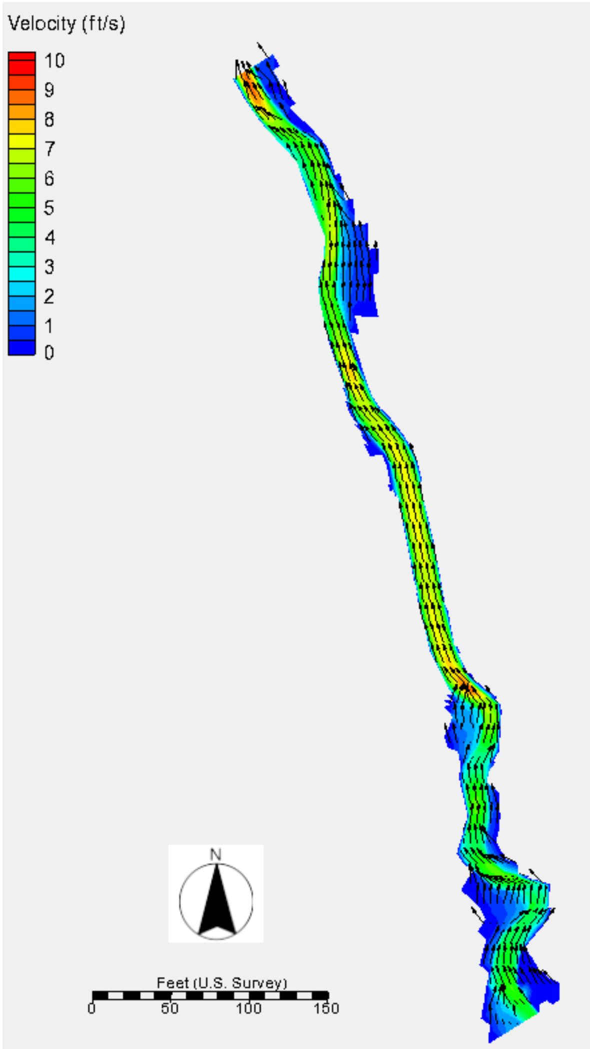

Figure 24 Proposed conditions 100-year velocity map

8.0 Fish Passage Design Methods Selection

8.1 Design Methodology Selection

The WCDG contains methodology for five different types of crossings: No-Slope Culverts, Stream Simulation Culverts, Bridges, Temporary Culverts or Bridges, and Hydraulic Design Fishways. The permanent federal injunction allows for the use of the stream simulation method and bridge design method unless extraordinary circumstances exist on site. According to the WCDG, a bridge should be considered for a site if the Floodplain Utilization Ratio (FUR) is greater than 3.0, the stream has a bankfull width of greater than 15 feet, the channel is believed to be unstable, the slope ratio exceeds 1.25 between the existing channel and the new channel, or the culvert would be very long. Using these design criteria, bridge criteria was deemed the most appropriate method for this crossing because the project is at a slope transition location that has a history of aggradation and degradation. It is also recommended that a bottomless structure be constructed to accommodate potential periods of degradation.

8.2 Bridge Design Criteria

The 2013 WDFW Water Crossing Design Guidelines (WCDG) present two methodologies for designing a bridge crossing—confined bridge design and unconfined bridge design. The method to be used is defined by the Floodplain Utilization Ratio (FUR). The FUR is defined as the flood-prone width (FPW) divided by the bankfull width. The FPW is the water surface width at twice the bankfull depth, or the width at the 50-year to 100-year flood. A ratio under 3.0 is considered a confined channel and above 3.0 is considered an unconfined channel. The downstream channel is very confined, therefore the upstream reach was used to estimate the FUR.

The upstream 100-year FPW varies upstream from approximately 20 to 25 feet when the backwater from the existing culvert is removed. Using a design bankfull width of 13 feet, the FUR varies from 1.5 to 1.9 feet. Therefore, the channel is considered a confined channel.

8.2.1 Confined Bridge Design Width Criteria

The proposed crossing is at a confined channel. The proposed structure size will follow the WCDG recommendation of span based on the agreed upon bankfull width, with the span being 1.2 x bankfull width + 2 feet (WCDG Equation 3.2). Using this equation, along with the measured bankfull width of 13 feet discussed in Section 5.0, results in a structure span of 17.6 feet. This was rounded up to the nearest whole foot of 18 feet.

8.2.2 Backwater and Freeboard

The WCDG recommends the prevention of excessive backwater rise and increased main channel velocities during floods that might lead to scour of the streambed and coarsening of the stream substrate, allow the free passage of debris expected to be encountered, and generally suggests a minimum 2 foot freeboard for streams of this size. It is practicable to meet the minimum 2 feet of freeboard at this crossing. It is recommended that the minimum freeboard be increased to 3 feet at this site to account for potential channel aggradation. This site has a history of degrading and aggrading by several feet downstream of the fish ladder in the past. It is also recommended that a bottomless structure be constructed to accommodate potential periods of degradation.

An additional consideration is that a minimum of 5 feet of clearance from the channel thalweg to the low chord be provided if practicable for constructability, future maintenance, and performing monitoring activity. The 100-year water surface depth is approximately 1.7 feet, adding 3 feet of freeboard does not meet the minimum recommended 5 foot of clearance. Therefore, the recommended structure should have 5 feet of clearance from the thalweg to meet the maintenance recommendation and exceed the freeboard requirement.

8.2.3 Channel Planform and Shape

The WCDG requires that the channel planform and shape mimic conditions within a reference reach. The proposed channel shape includes 20H:1V slopes between the toes, with a 2 foot high 2H:1V bank slope on the right bank with 5H:1V floodplain grading above that. The left bank is graded at 2H:1V until it catches existing grade as it's up against a steeper hillside. The typical channel section is illustrated in Figure 25.

Channel habitat features will be implemented to create channel complexity. See Section 9.4 for further descriptions of the channel habitat features. A low flow channel will be added in later stages of the project that connect habitat features together and ensure the project is not a low flow barrier. The low flow channel will be as directed by the Engineer in the field.

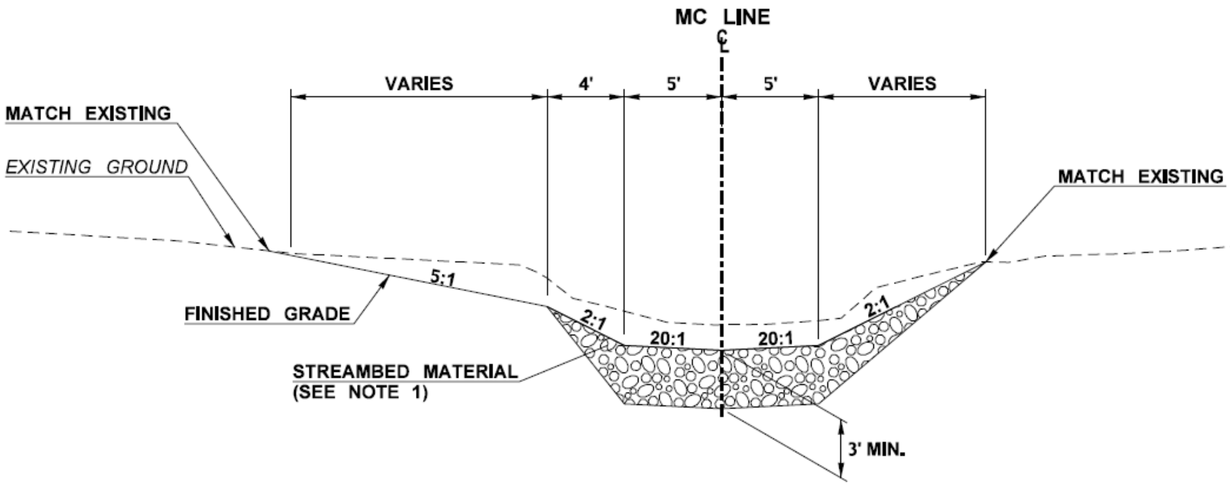

Figure 25 Typical channel section (looking upstream)

8.2.4 Floodplain Continuity and Lateral Migration through Structure

The WCDG requires that bridges account for lateral channel movement that will occur in their design life and that the design channel maintains floodplain continuity. The existing channel upstream of shows some lateral migration several hundred feet upstream of the crossing. Most of the migration appears to be localized due to large wood that had fallen into the channel. However, directly upstream of the crossing and downstream of the crossing no signs of lateral migration were observed.

8.2.5 Channel Gradient

The WCDG recommends that the proposed culvert bed gradient not be more than 25% steeper than the existing stream gradient upstream of the crossing (WCDG Equation 3.1). The proposed channel gradient is 2.7%. The upstream average gradient is approximately 1.7% for 250 feet upstream of the existing culvert and then transitions to approximately 3.0% upstream of that. The downstream average gradient is approximately 2.4%. It was determined to use the downstream gradient for the slope ratio comparison due to the upstream impacts associated with the undersized existing structure. The resulting slope ratio for the downstream reach is 1.1.

9.0 Streambed Design

9.1 Alignment

The proposed project alignment closely follows the existing alignment. Channel grading will extend approximately 85 feet downstream of the existing culvert and 60 feet upstream of the existing culvert.

9.2 Proposed Section

Description of the existing and proposed cross section are presented in Section 8.2.3. A low flow channel will be added in later stages of the project that connect habitat features together and ensure the project is not a low flow barrier. The low flow channel will be as directed by the Engineer in the field.

9.3 Bed Material

The proposed bed material gradation was created using standard WSDOT specification material to mimic the gradation documented in the pebble count as best possible. The proposed mix will consists of one part Streambed Sediment to one part 4-inch Streambed Cobbles. A comparison of the observed and proposed streambed material size distribution is provided in Table 7. McDonald Creek has a history of varying bed loads with aggradation and degradation from year to year varying by several feet. Therefore it was deemed most appropriate to match the existing material that is anticipated to be delivered from the upstream reach.

Table 7 Comparison of observed and proposed streambed material

Particle	Observed Material Diameter (in)	Proposed Material Diameter (in)
D_{15}	0.3	0.2
D_{50}	1.3	1.3
D_{84}	2.8	2.6
D_{95}	3.5	3.5
D_{100}	5.0	4.0

9.4 Channel Habitat Features

Large Woody Material will be installed in portions of McDonald Creek. The LWM installations will provide structure conducive to create stream complexity and geomorphic functions in segments that will have low natural LWM delivery rates while new and impacted riparian areas recover from construction activities related to the installation of the new crossing and the regrading of the stream channels. LWM, in conjunction with habitat boulders and bank-side bioengineering, will also help protect newly constructed banks and will promote long-term stability by creating pools, sinuosity, hard points, and channel roughness.

9.4.1 Design Concept

The 75th percentile of key piece density per Fox and Bolton (2007) and Chapter 10 of the Hydraulics Manual recommend 3.3 key pieces per 100 feet of channel. This percentile of wood placement is suggested to compensate for cumulative deficits of wood loading due to development. A conceptual LWM layout has been developed for the McDonald Creek project area and is provided in Figure 26. The conceptual layout proposes 11 key pieces. The project reach is 205 feet long (including the structure) yielding 5.4 key pieces per 100 feet of linear channel, 64% more than the Fox and Bolton (2007) 75th percentile criteria to account for portions of the channel where infrastructure limits LWM placement. LWM has not been explicitly included in the proposed conditions hydraulic model, but should be updated for future design phases. The conceptual layout also includes boulder clusters under the structure to provide stream complexity under the structure.

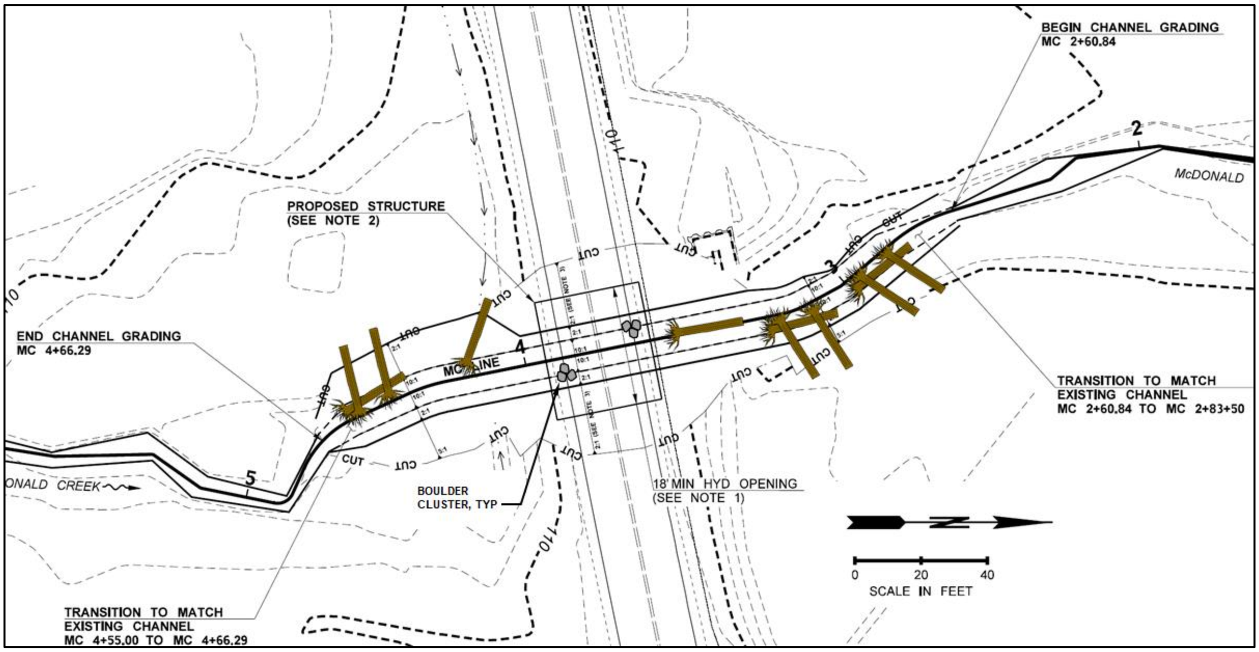

Figure 26 Proposed grading and conceptual wood layout

10.0 Floodplain Changes

This project is not within FEMA mapped floodplain.

10.1 Floodplain Storage

Placement of fill associated with the proposed project is limited to the scour hole downstream of the culvert. Material will be removed from the floodplain and channel as a result of replacing undersized culvert with a larger structure, removal of the fish ladder, upstream channel grading (cut) and removal of the existing roadway embankment. The installation of a larger hydraulic opening reduces the amount of backwater being stored upstream of the crossing and reduces any peak flow attenuation that was being provided by the smaller, existing crossing. Changes to peak flow reduction were not quantified as the models were run in a quasi-steady state flow with a constant flow rate specified at the upstream boundary of the model.

10.2 Water Surface Elevations

Installation of the proposed structure will eliminate the backwater impacts upstream of the existing culvert, resulting in a reduction in water surface elevation. Preliminary hydraulic results indicate that there is a reduction in water surface elevation as high as 3.8 feet during the 100-year event (Figure 27) immediately upstream of the culvert inlet. A small rise in the 100-year water surface of approximately 0.3 feet occurs downstream of the crossing and is a result of filling the existing scour hole.

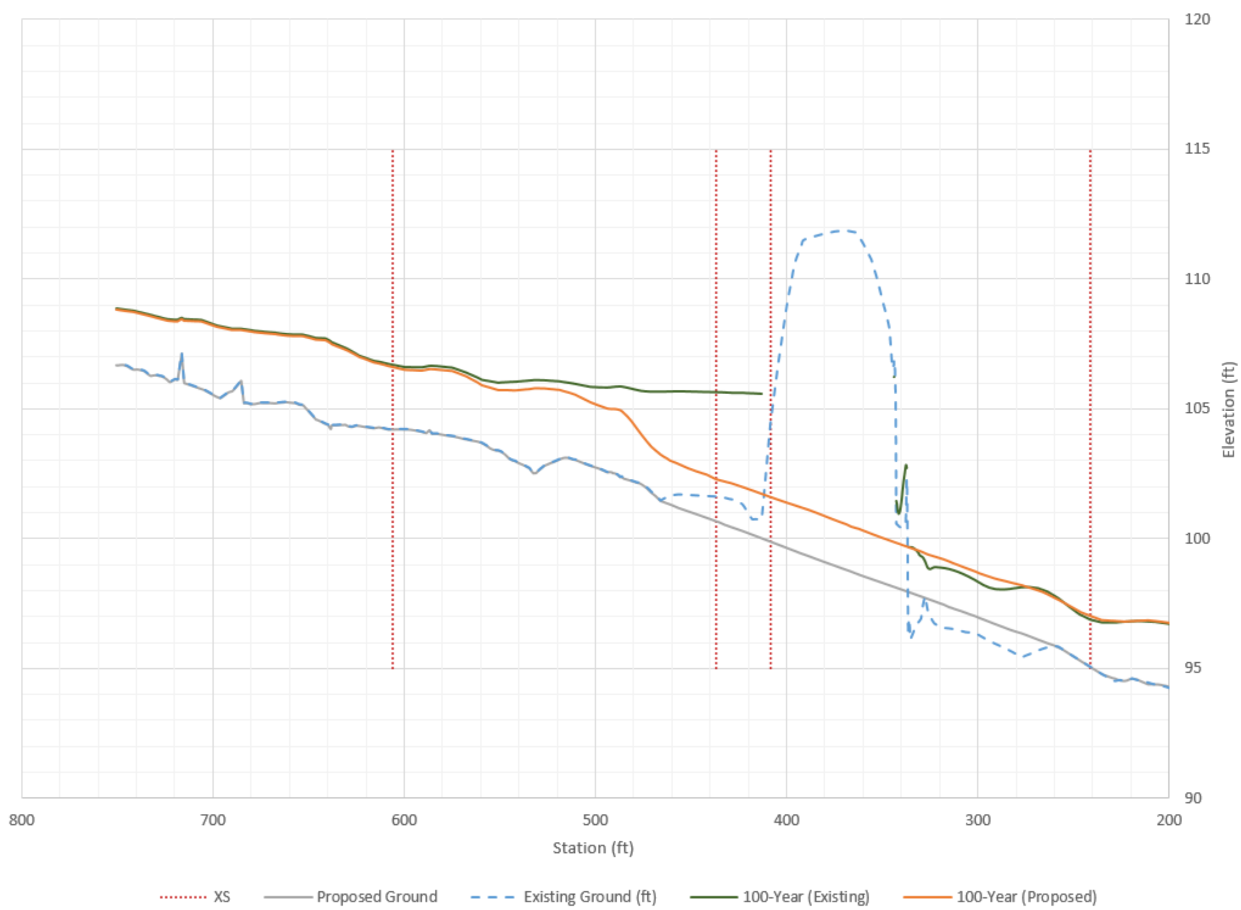

Figure 27 Existing and proposed 100-year water surface profile comparison

11.0 Climate Resilience

WSDOT recognizes climate resilience as a component of the integrity of its structures and approaches the design of bridges, and buried structures through a risk based assessment beyond the design criteria. For bridges and buried structures, the largest risk to the structures will come from increases in flow and/or sea level rise. The goal of fish passage projects is to maintain natural channel processes through the life of the structure and maintain passability for all expected life stages and species in a system.

11.1 Climate Resilience Tools

Climate resilience is evaluated at each crossing using the Climate Impacts Vulnerability Assessment Maps created by WSDOT to assess risk level of infrastructure across the state. The SR 108 crossing at McDonald Creek has been evaluated and determined to be a low risk site based on the Climate Impacts Vulnerability Assessment Maps.

WSDOT also evaluates crossings using the mean percent change in 100-year flood flows from the WDFW Future Projections for Climate-Adapted Culvert Design program. For low or medium risk sites, the 2040 percent increase is used. For high risk sites the 2080 percent increase is used. Appendix E contains the information received from WDFW for this site. The 100-year flow event was chosen to be evaluated, because, as it is an extreme event, if the channel behaves similarly through the structure during this event as it does the adjacent reaches, then it is anticipated this relationship would also be true at lower flows as well.

11.2 Hydrology

For each design WSDOT uses, the best available science for assessing site hydrology. The predicted flows are analyzed in the hydraulic model and compared to field and survey indicators, maintenance history, and any other available information. Hydraulic engineering judgment is used to compare model results to system characteristics; if there is significant variation, then the hydrology is re-evaluated to determine whether or not adjustments need to be made, including adding standard error to the regression equation, basin changes in size or use, etc.

In addition to using the best available science for current site hydrology, WSDOT is evaluating the structure at the 2040 projected 100-year flow event to check for climate resiliency. The Design Flow for the crossing 134 cfs at the existing 100-year storm event. The projected increase for the 2040 flow rate is 9.4%, yielding a projected 2040 flow rate of 147 cfs.

11.3 Structure Width

The minimum width for a crossing given by Equation 3.2 was 17.6 feet. Structures come in whole foot increments for width, as a result, the width was increased to 18 feet to accommodate constructability and manufacturability. This structure width was evaluated at the 100-year flow event and projected 2040 100-year flow event and determined to produce similar velocities through the structure and adjacent reaches, indicating that the structure span would not need to be increased to accommodate the 2040 100-year flow event. The velocity comparisons for these flow rates can be seen in Table 8 below.

Table 8 Velocity comparison for 18 foot structure

	100-Year Velocity (ft/s)	Projected 100-Year Velocity (ft/s)	Difference (ft/s)	Difference (%)
Upstream of Structure	6.31	6.51	0.2	3.2%
Through Structure	6.14	6.40	0.26	4.2%
Downstream of Structure	6.63	6.87	0.24	3.6%
Velocity Ratio	1.03	1.02	-	-

Note: Velocity ratio calculated as Vstructure/Vupstream

11.4 Freeboard and Countersink

The minimum recommended freeboard at this location based on bankfull width is 2 feet at the 100-year flow event. However, the design freeboard at this project was increased to 3 feet to account for possible aggradation. The 100-year flow has an approximate flow depth of 1.7 feet at the 100-year flow event and 1.8 feet at the 2040 projected 100-year flow event. The proposed design provides 5 feet of clearance from the thalweg, which results in 3.3 feet of freeboard at the 100-year and 3.2 feet of freeboard at the 2040 projected 100-year flow event, exceeding the freeboard requirement.

Long term degradation and aggregation, contraction scour and local scour were not evaluated for this preliminary hydraulic design and will need to be evaluated during the final design. Pending the outcome of the scour analysis, the preliminary design and depth of countersink will be revised to account for the total potential scour associated with the projected 2040 100-year flow event. However, it is recommended that a bottomless structure be constructed to accommodate degradation that has been observed in previous years.

11.5 Summary

A minimum hydraulic opening of 18 feet and a minimum freeboard of 3 feet allows for the channel to behave similarly through the structure as it does in the adjacent reaches under the projected 2040 100-year flow event. This will provide a robust structure design that is resilient to climate change and allow the system to function naturally, including the passage of sediment, debris and water in the future.

12.0 Scour Analysis

Scour calculations were not performed during the preliminary design, but will be performed following the procedures outlined in *Evaluating Scour at Bridges HEC No. 18* (Arneson et al. 2012) during final design. Scour components to be considered in the analysis include:

1. Long-term aggradation/degradation
2. General scour (i.e., contraction scour)
3. Local scour

In addition to the three scour components above, potential lateral migration of a channel must be assessed when evaluating total scour at highway infrastructure.

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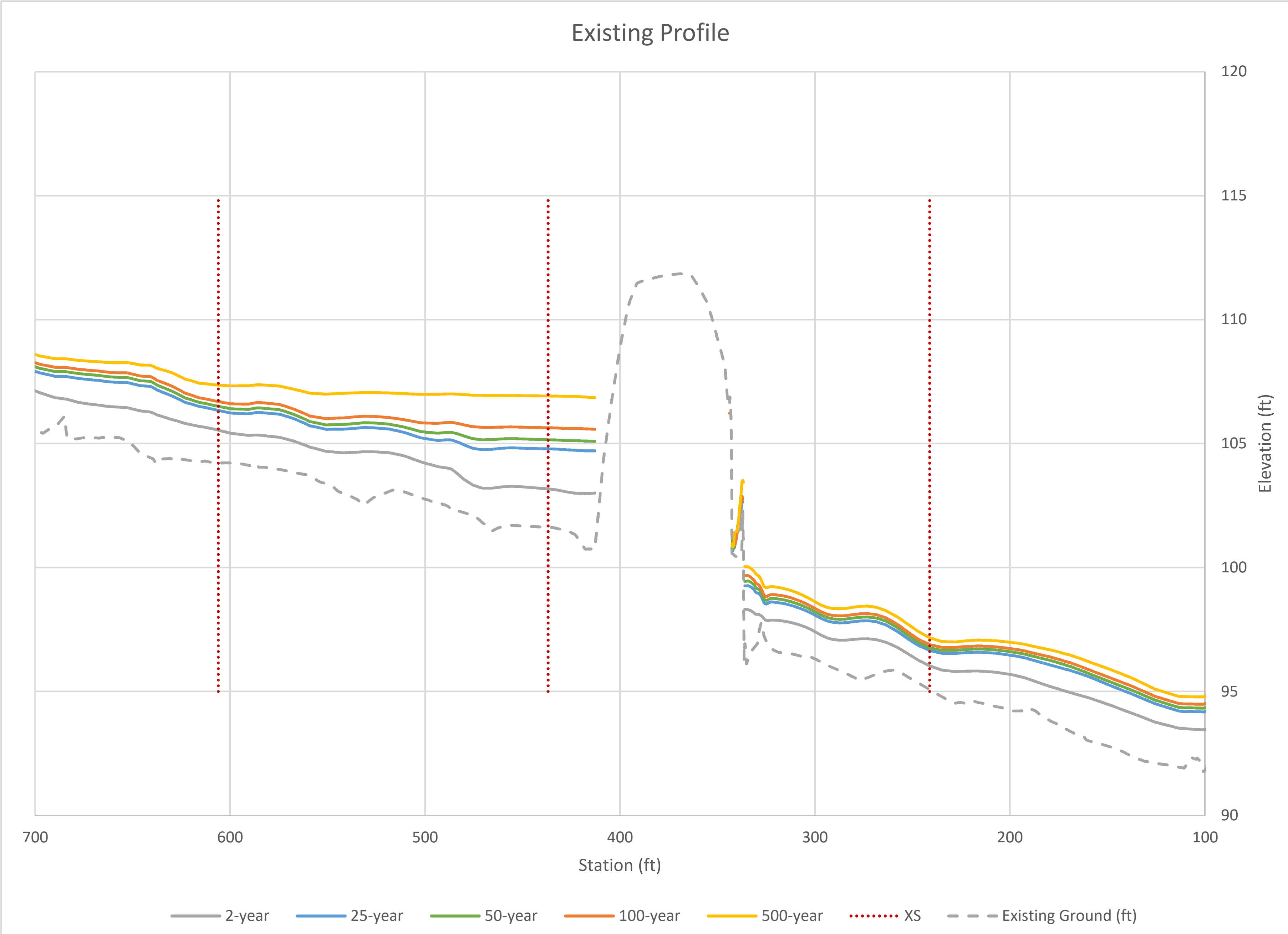
14.0 Appendices

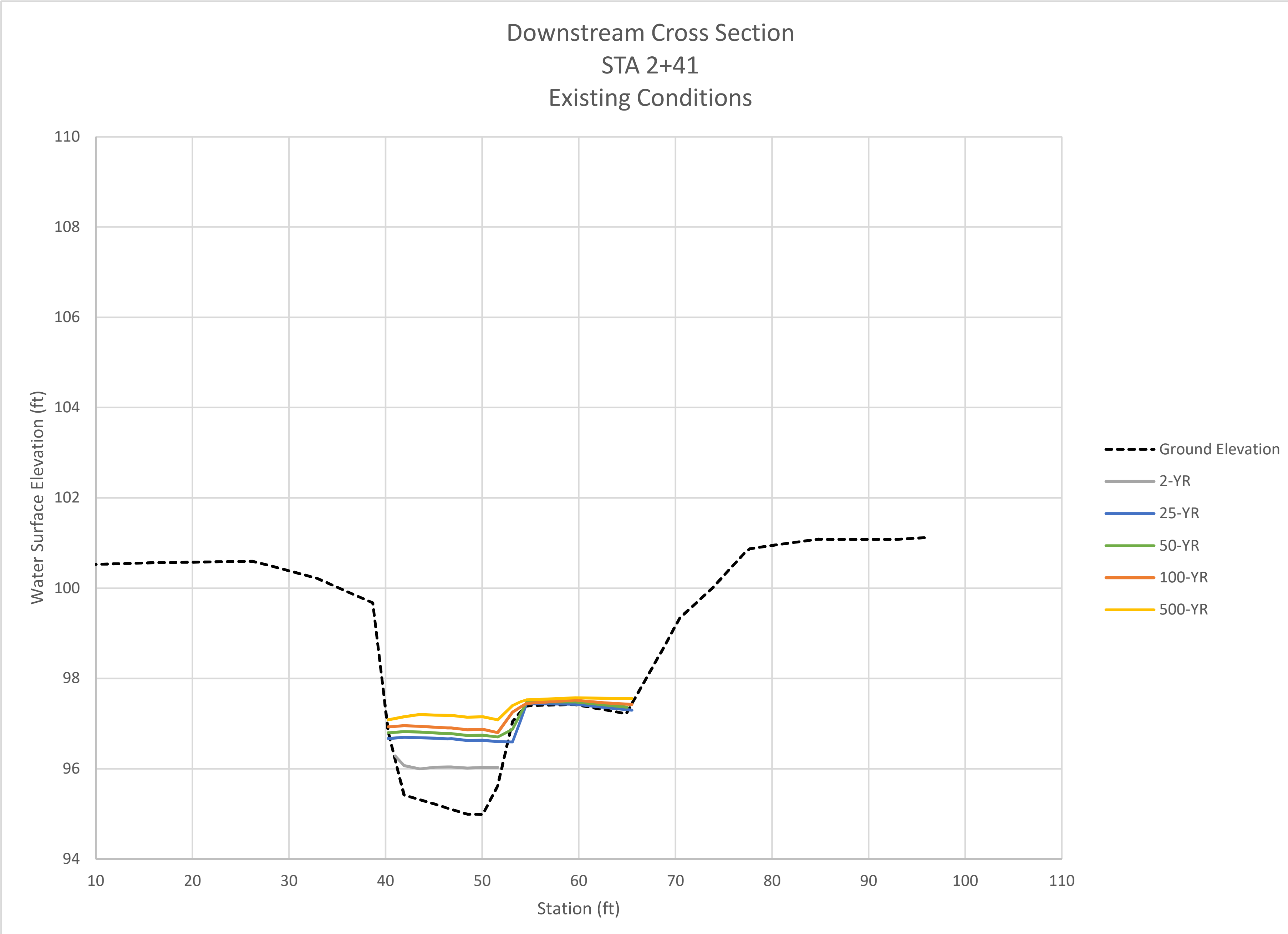
Appendix A – SRH-2D Model Results

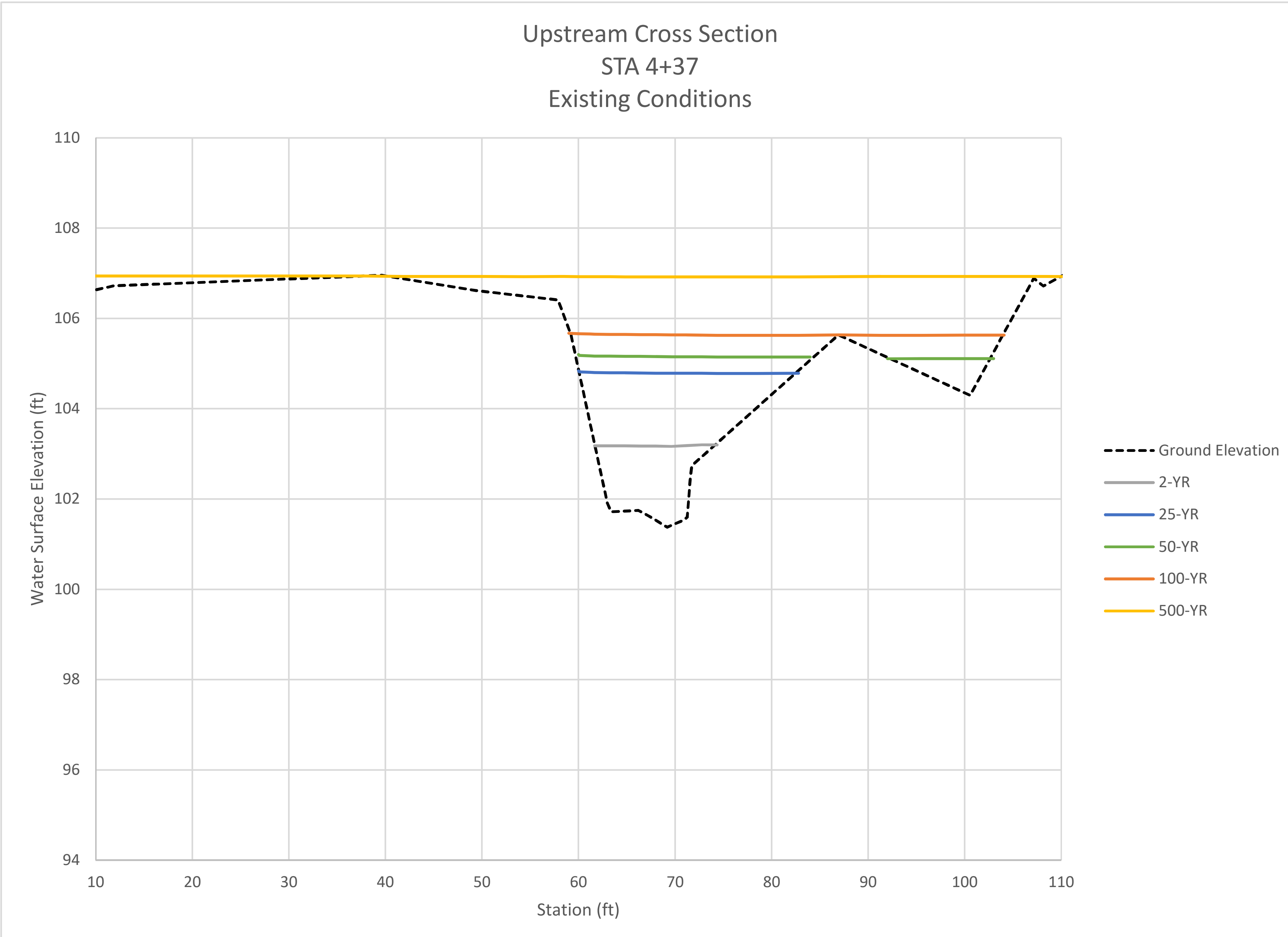
Appendix B – Stream Plan Sheets, Profile, Details

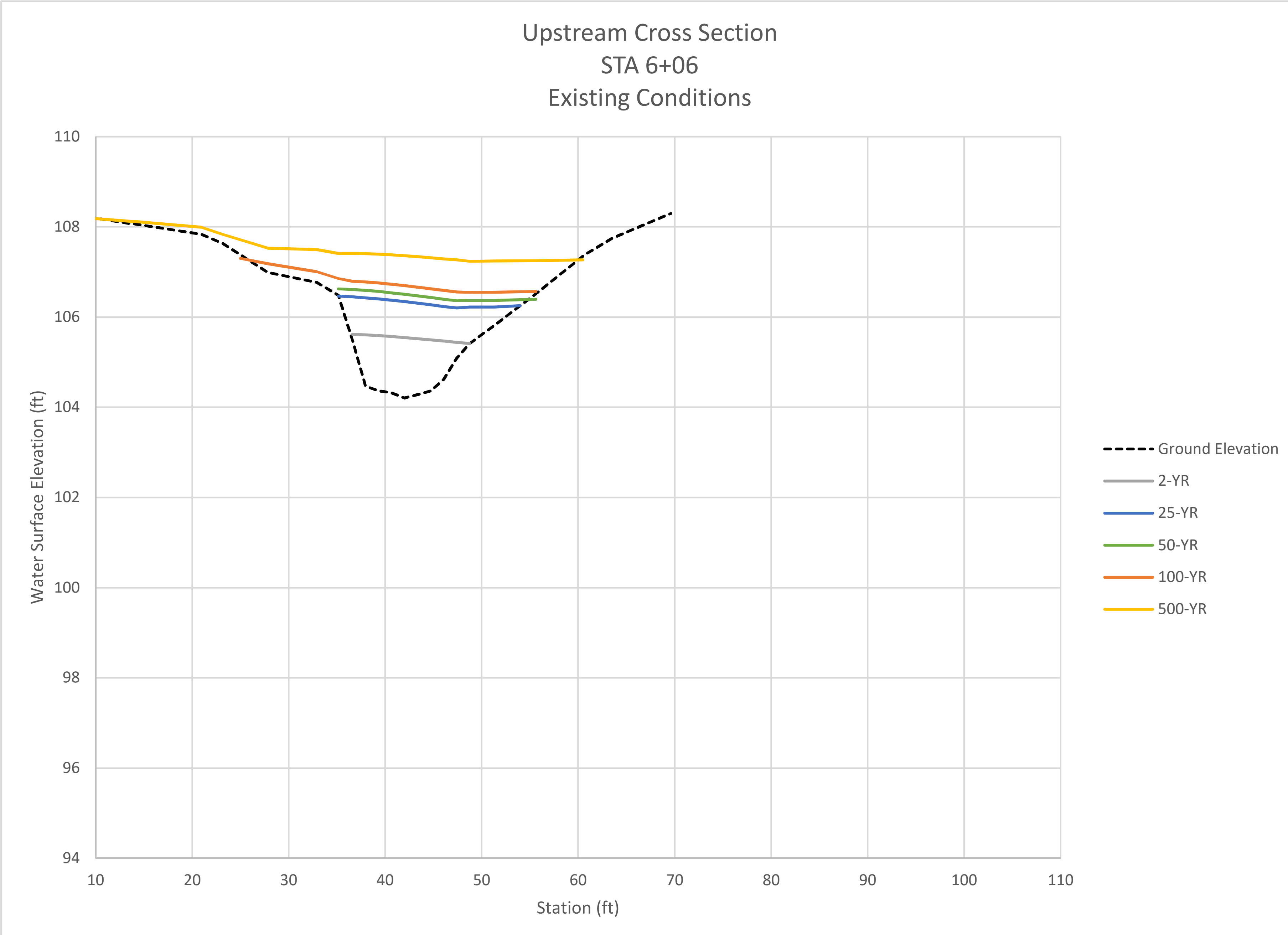
Appendix C – WDFW Future Projections for Climate-Adapted Culvert Design Printout

Appendix A – SRH-2D Model Results


Existing Profile
120
115
110
105
100
95
90
Elevation (ft)
700
600
500
400
300
200
100
Station (ft)
2-year
25-year
50-year
100-year
500-year
XS
Existing Ground (ft)


Downstream Cross Section
STA 2+41
Existing Conditions
Water Surface Elevation (ft)
110
108
106
104
102
100
98
96
94
10
20
30
40
50
60
70
80
90
100
110
Station (ft)
Ground Elevation
2-YR
25-YR
50-YR
100-YR
500-YR


Upstream Cross Section
STA 4+37
Existing Conditions
Water Surface Elevation (ft)
110
108
106
104
102
100
98
96
94
10
20
30
40
50
60
70
80
90
100
110
Station (ft)
Ground Elevation
2-YR
25-YR
50-YR
100-YR
500-YR


Upstream Cross Section
STA 6+06
Existing Conditions
Water Surface Elevation (ft)
Station (ft)
110
108
106
104
102
100
98
96
94
10
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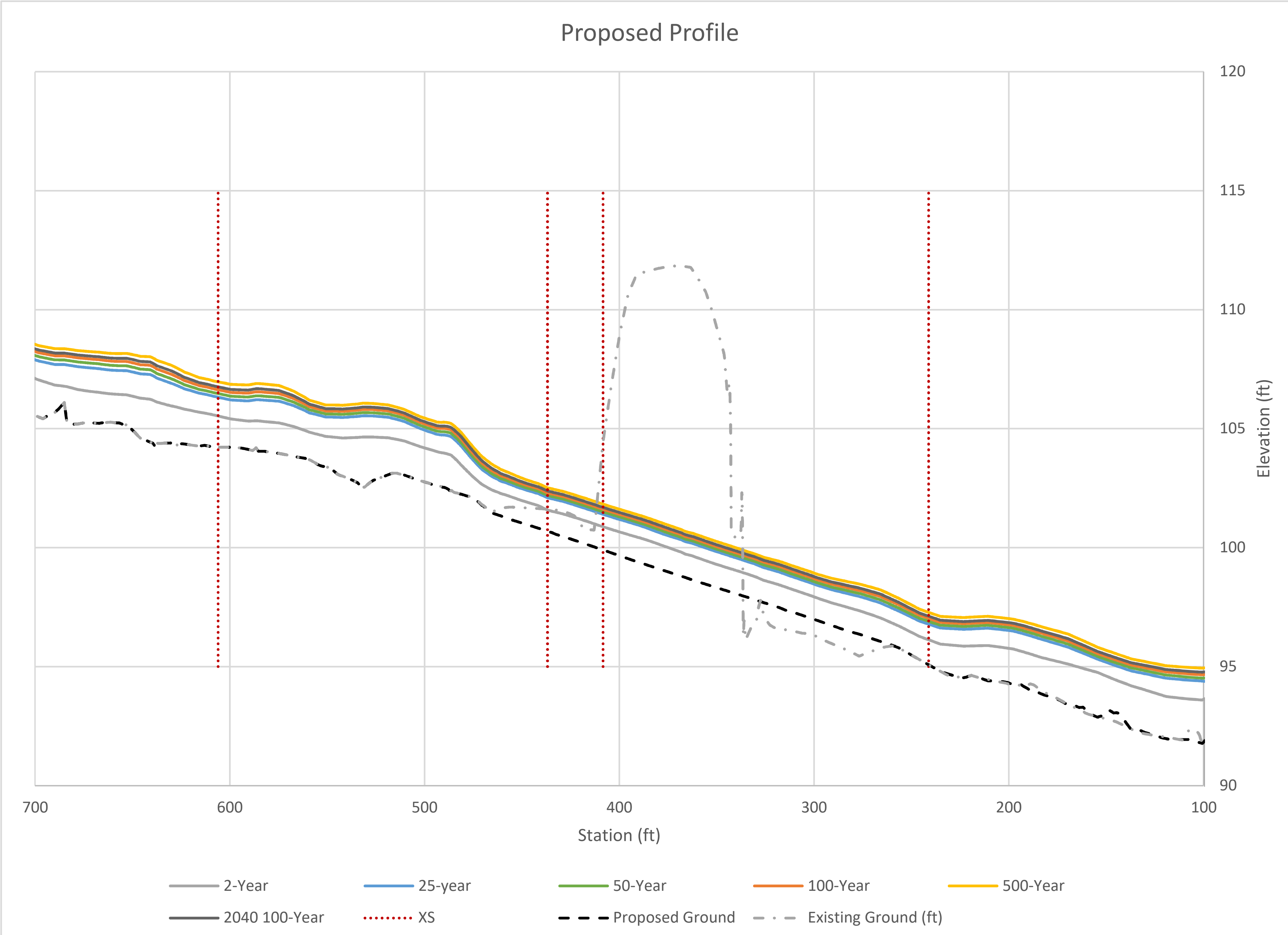
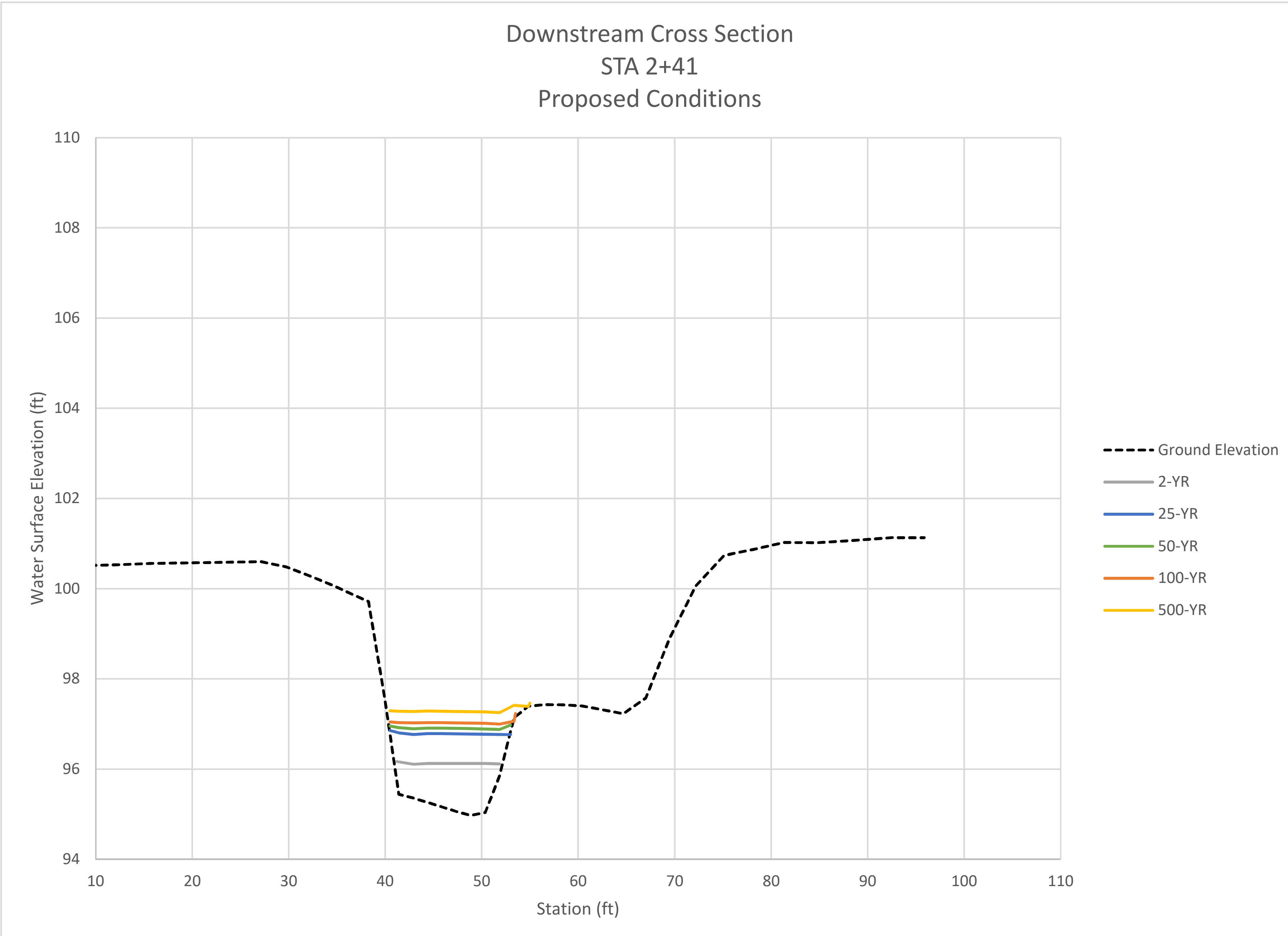
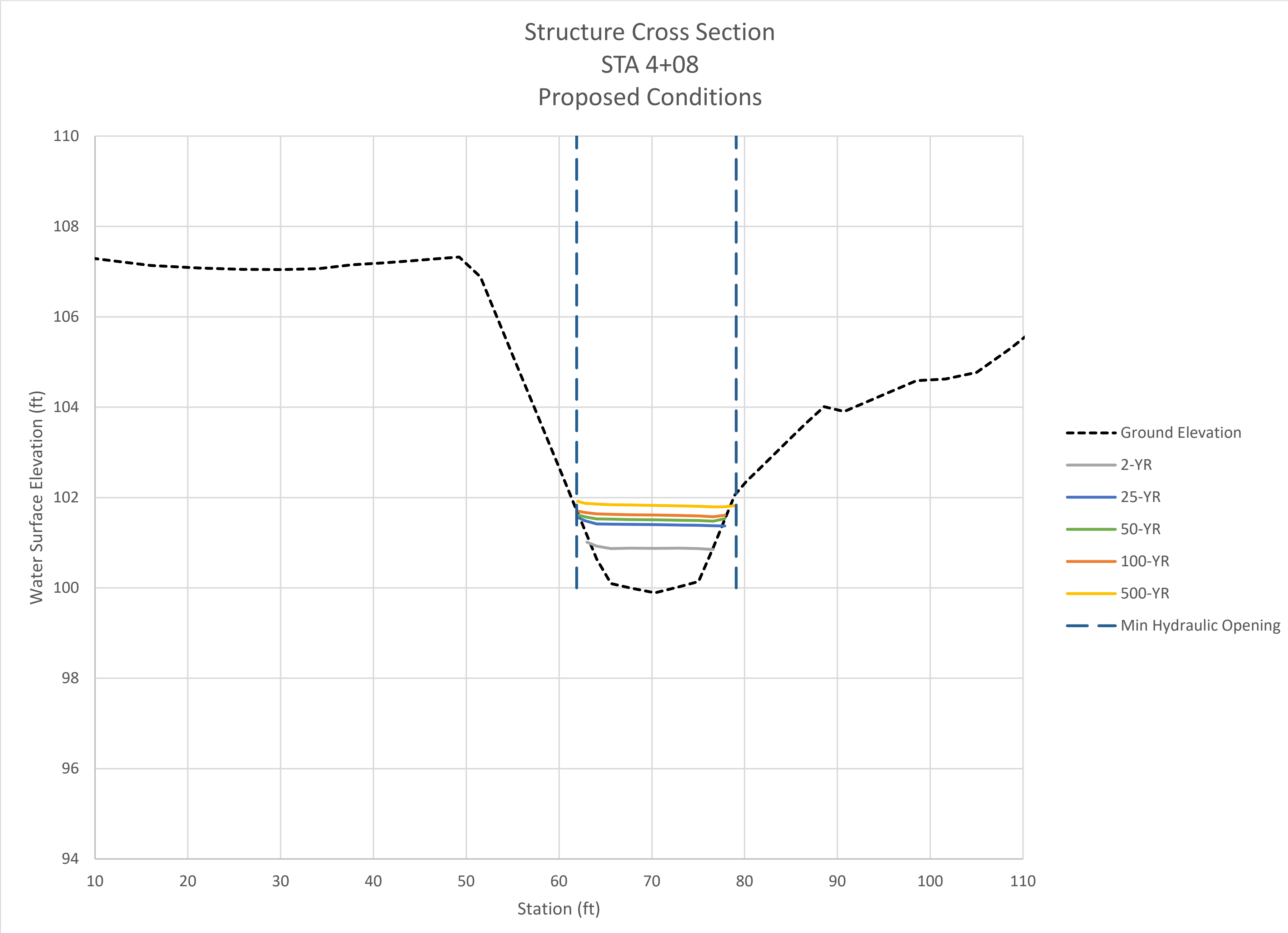
Ground Elevation
2-YR
25-YR
50-YR
100-YR
500-YR


Proposed Profile
120
115
110
105
100
95
90
Elevation (ft)
700
600
500
400
300
200
100
Station (ft)
2-Year
25-year
50-Year
100-Year
500-Year
2040 100-Year
XS
Proposed Ground
Existing Ground (ft)



Downstream Cross Section
STA 2+41
Proposed Conditions
Water Surface Elevation (ft)
110
108
106
104
102
100
98
96
94
10
20
30
40
50
60
70
80
90
100
110
Station (ft)
Ground Elevation
2-YR
25-YR
50-YR
100-YR
500-YR


Structure Cross Section
STA 4+08
Proposed Conditions
Water Surface Elevation (ft)
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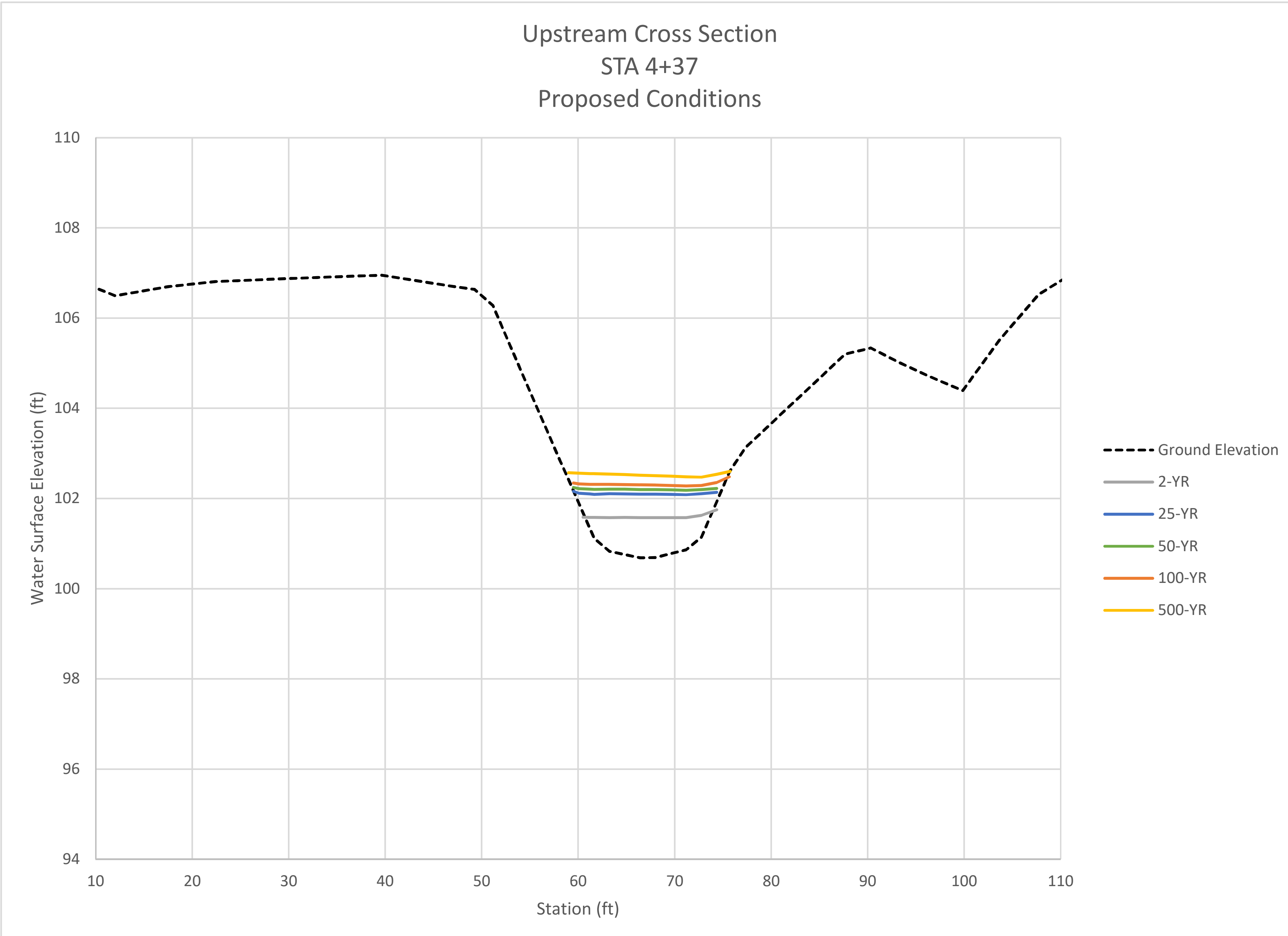
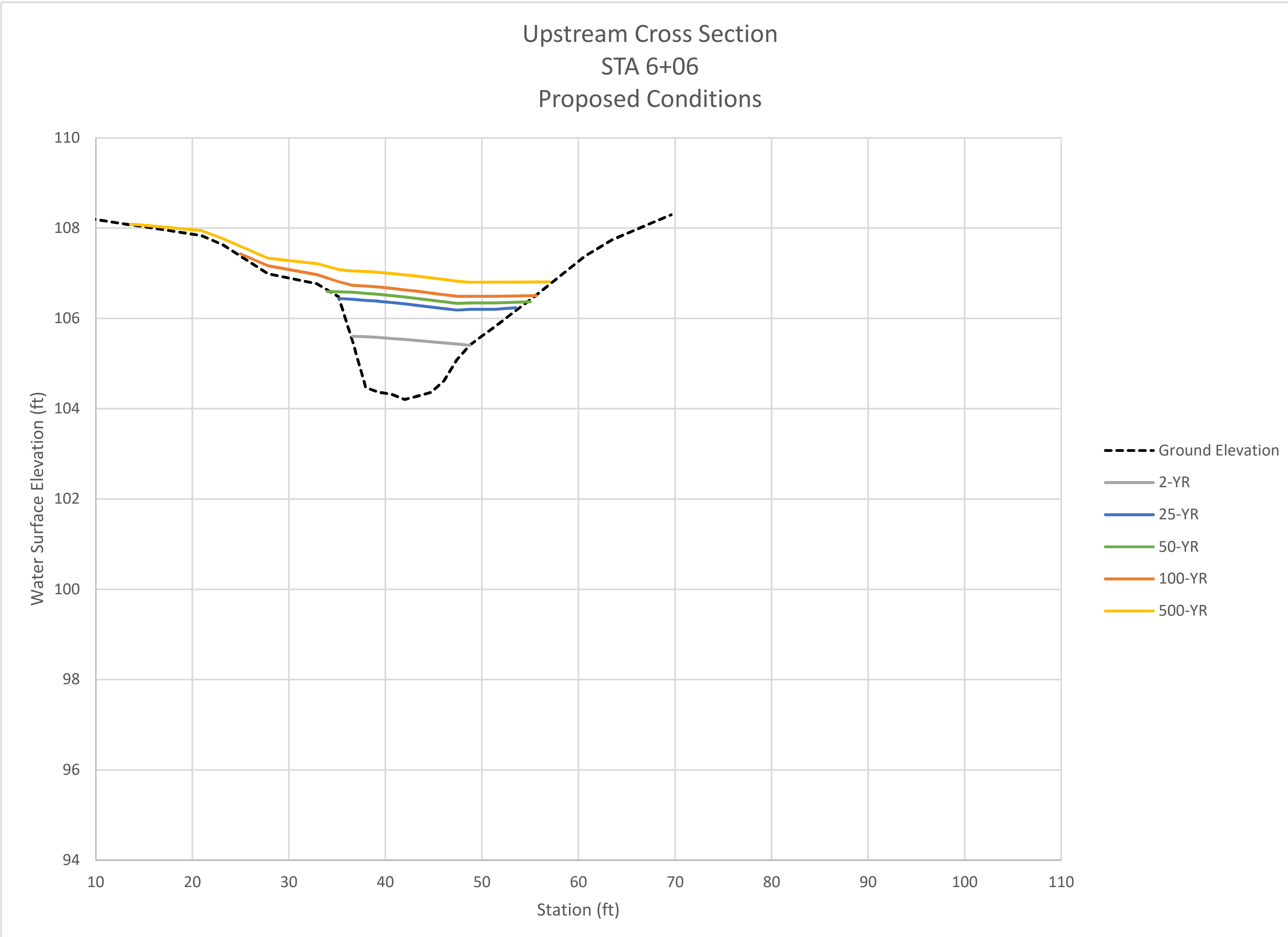
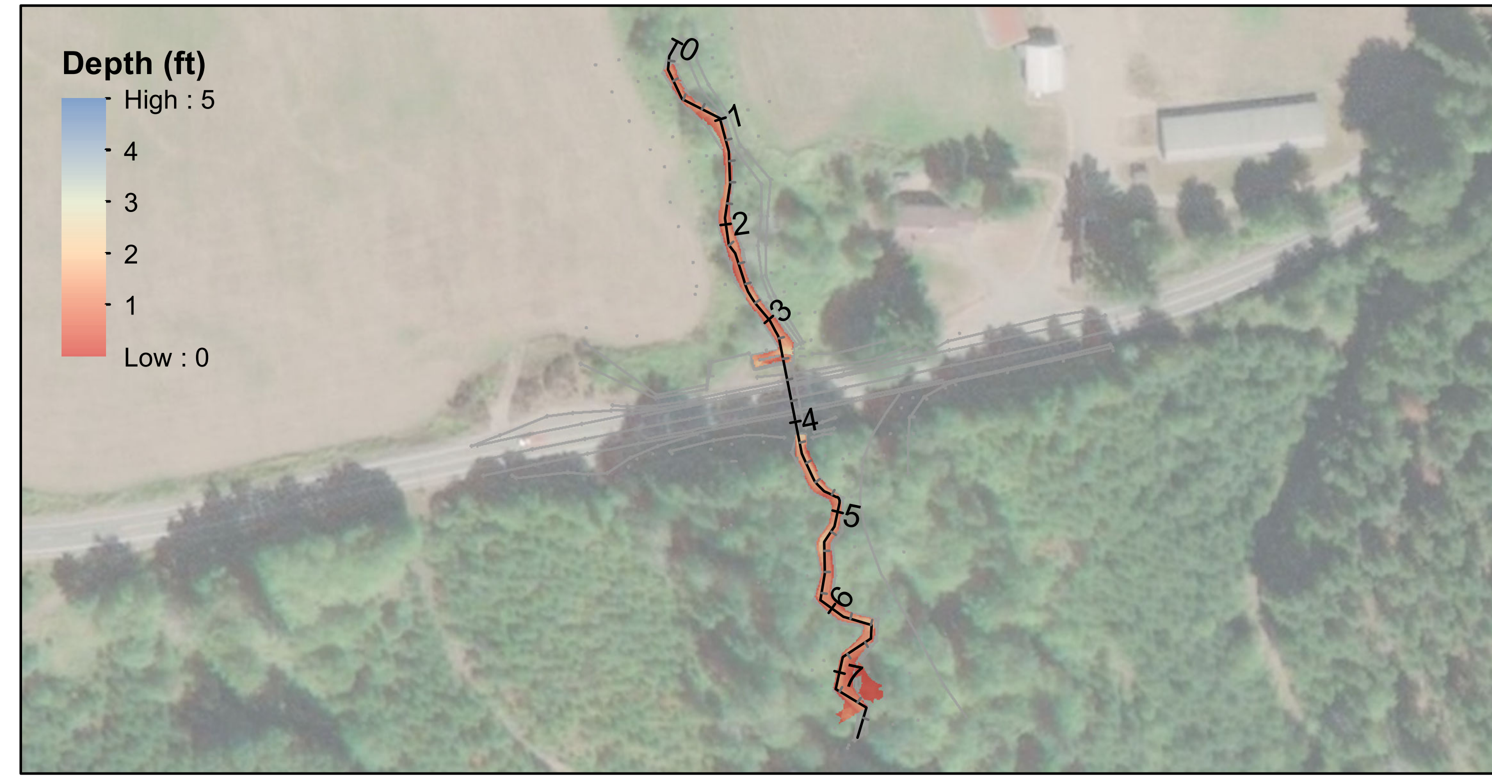
108
106
104
102
100
98
96
94
10
20
30
40
50
60
70
80
90
100
110
Station (ft)
Ground Elevation
2-YR
25-YR
50-YR
100-YR
500-YR
Min Hydraulic Opening


Upstream Cross Section
STA 4+37
Proposed Conditions
Water Surface Elevation (ft)
110
108
106
104
102
100
98
96
94
10
20
30
40
50
60
70
80
90
100
110
Station (ft)
Ground Elevation
2-YR
25-YR
50-YR
100-YR
500-YR

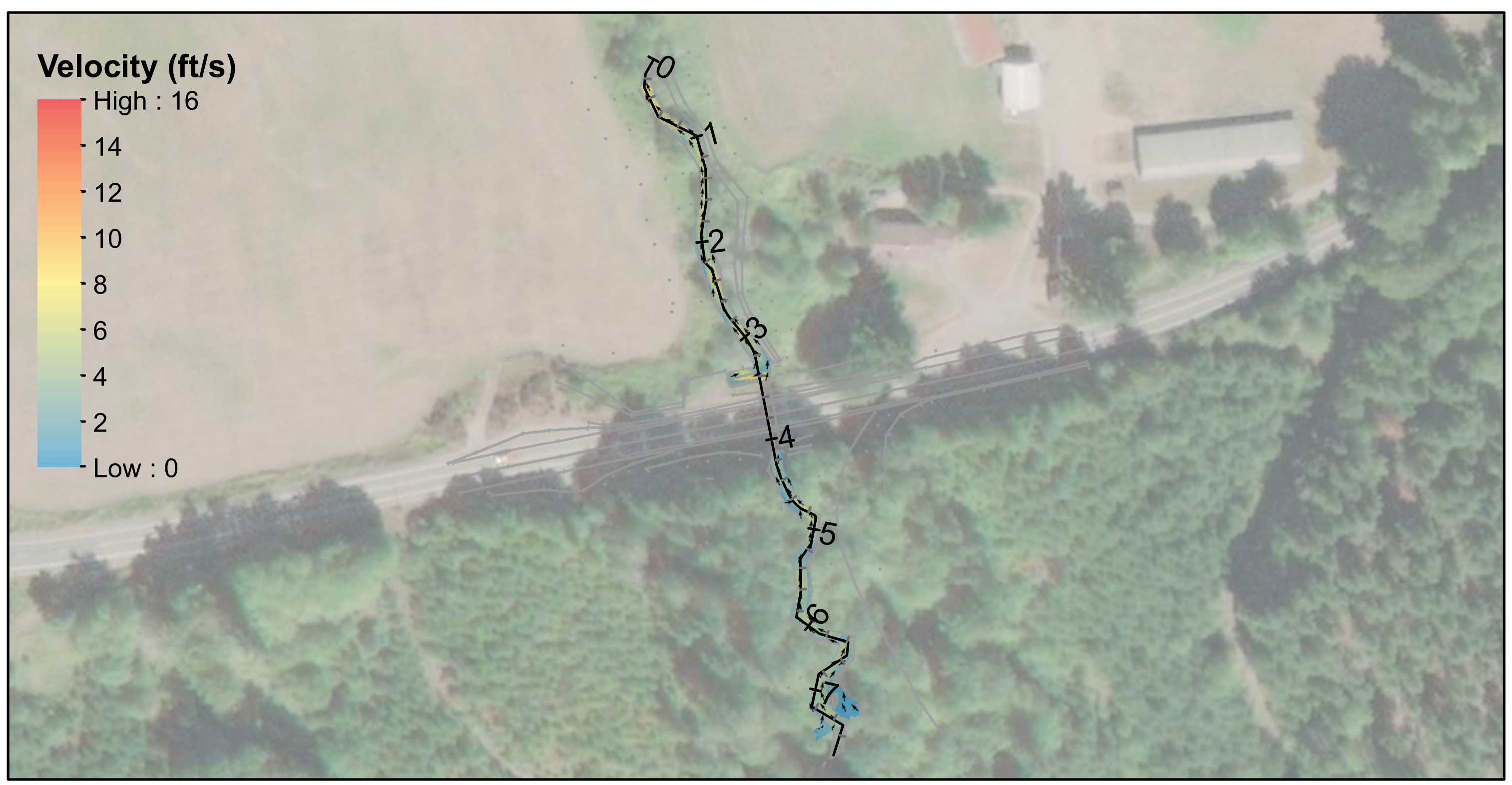


Upstream Cross Section
STA 6+06
Proposed Conditions
Water Surface Elevation (ft)
Station (ft)
110
108
106
104
102
100
98
96
94
10
20
30
40
50
60
70
80
90
100
110
Ground Elevation
2-YR
25-YR
50-YR
100-YR
500-YR

WATER SURFACE ELEVATION



DEPTH



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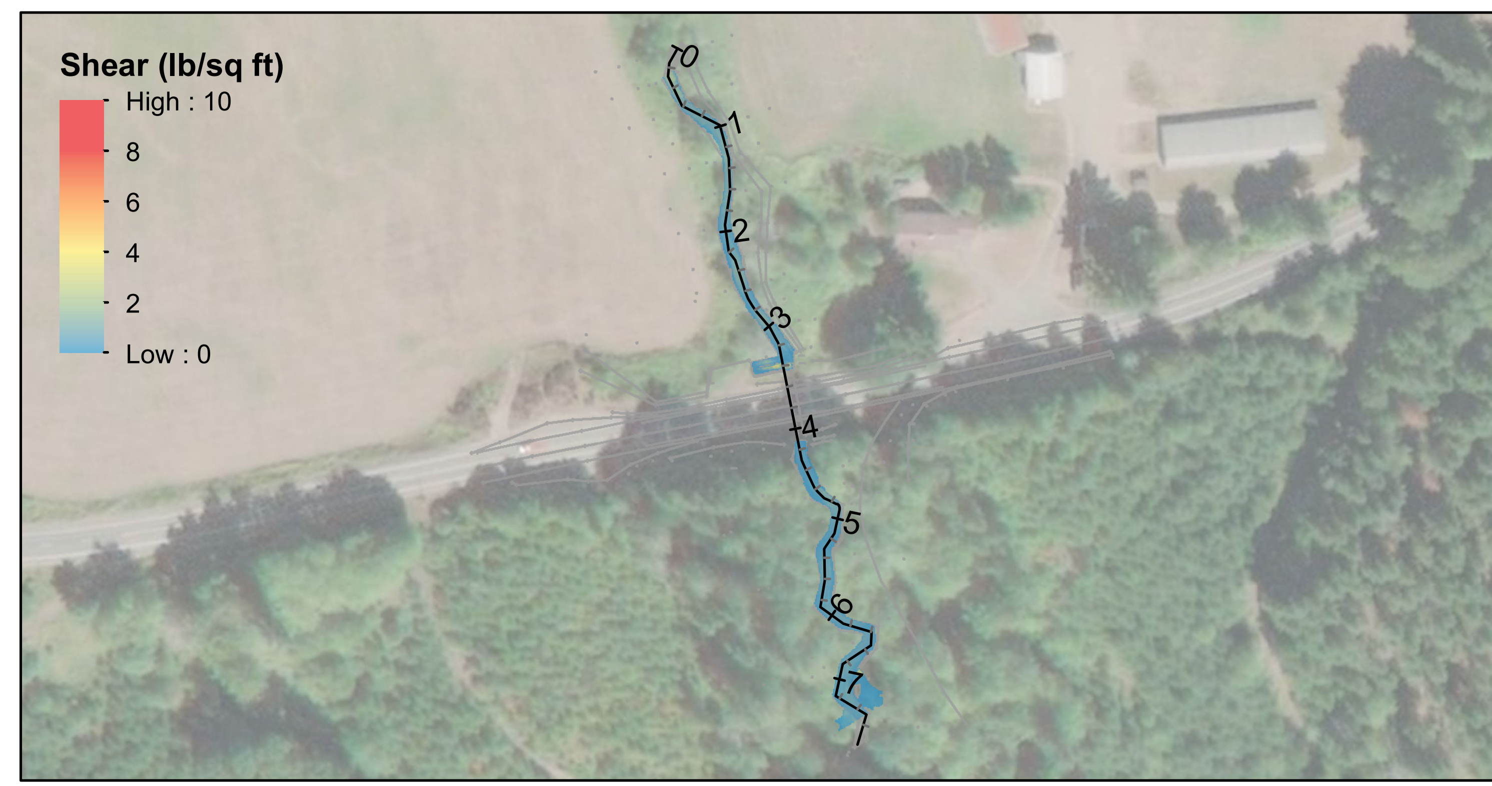


SHEAR

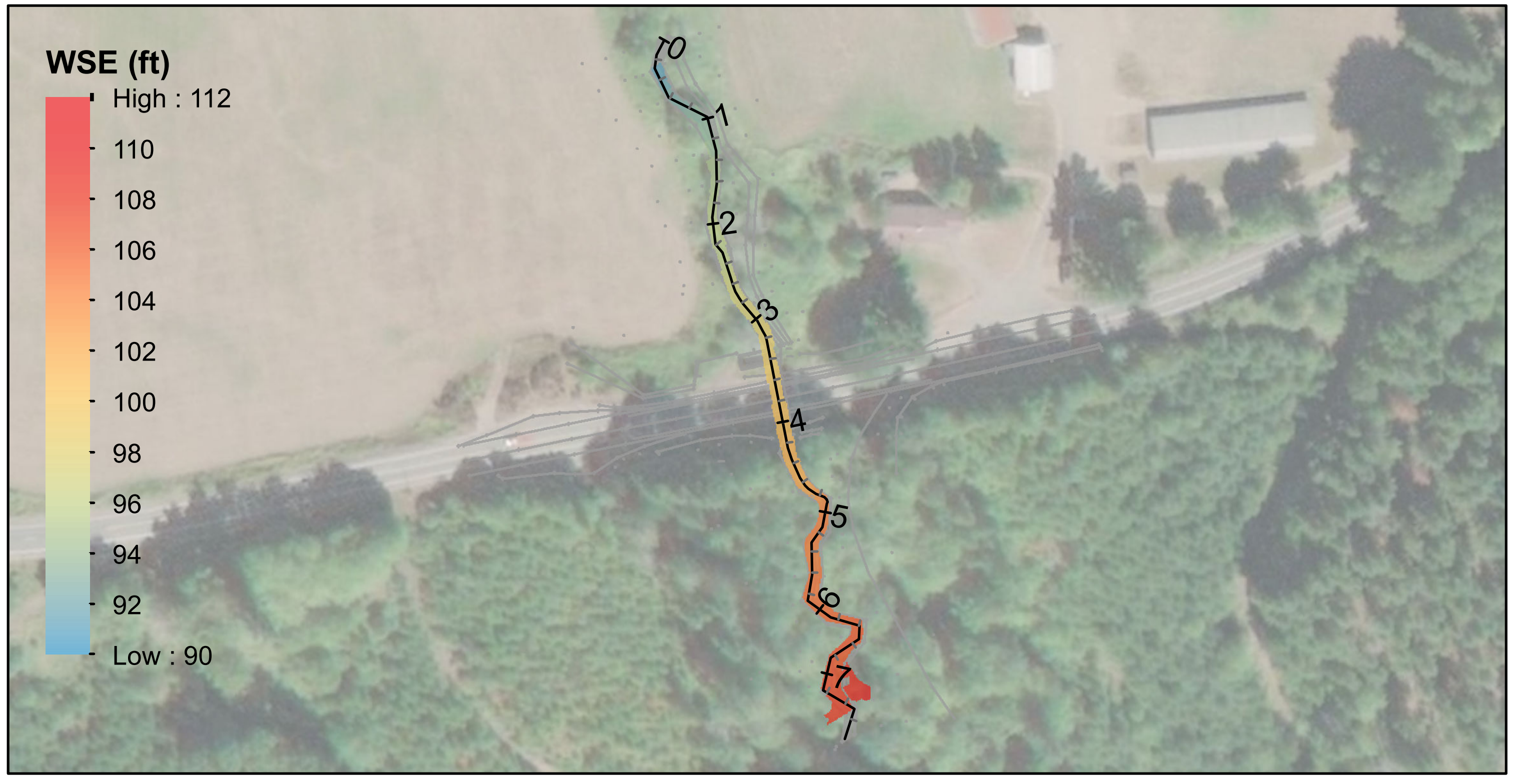
N

0 100 200 Feet

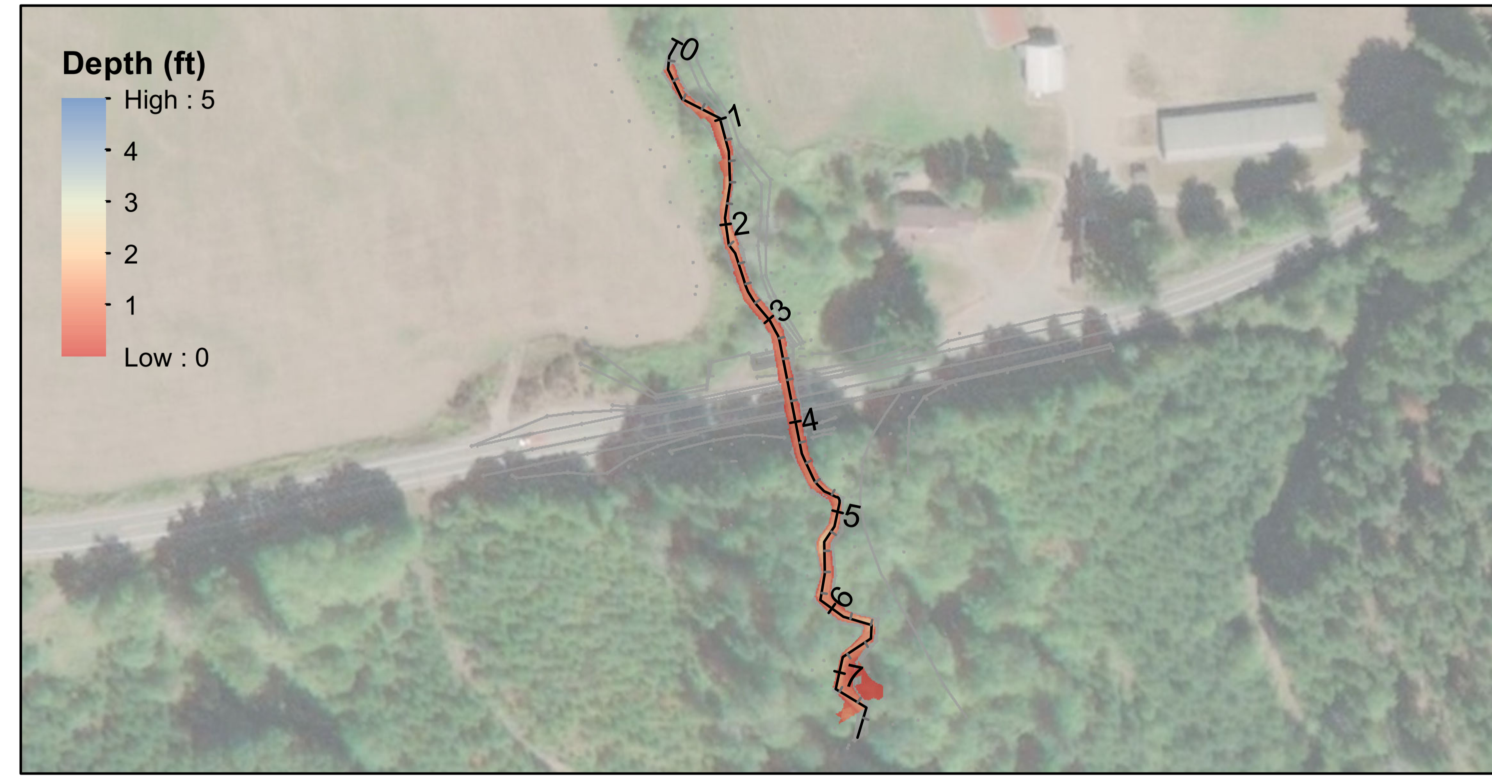
Washington State Department of Transportation

EXISTING CONDITIONS - 2 YEAR EVENT

SR 108 MCDONALD CREEK
MP 8.89



WATER SURFACE ELEVATION



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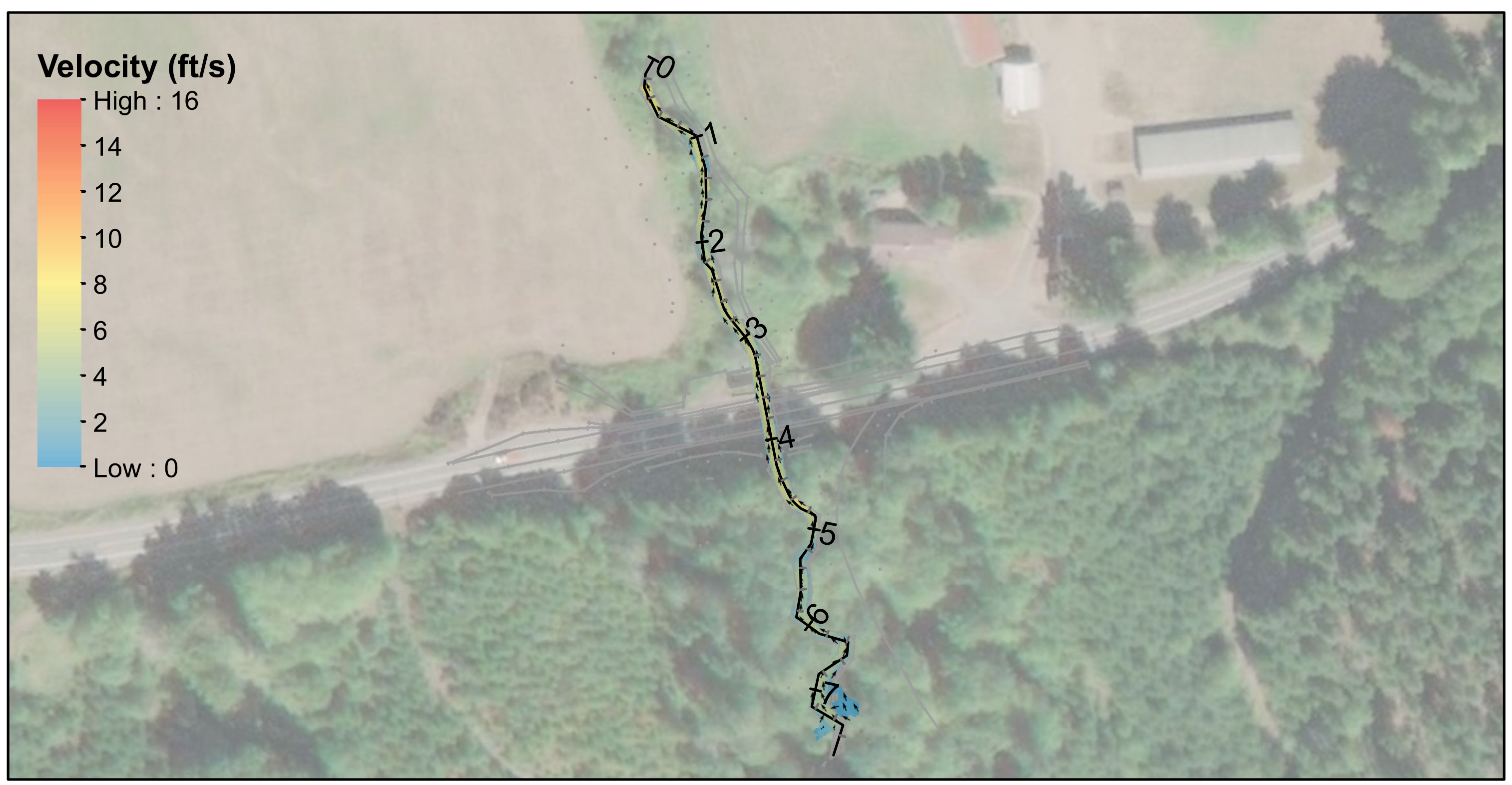

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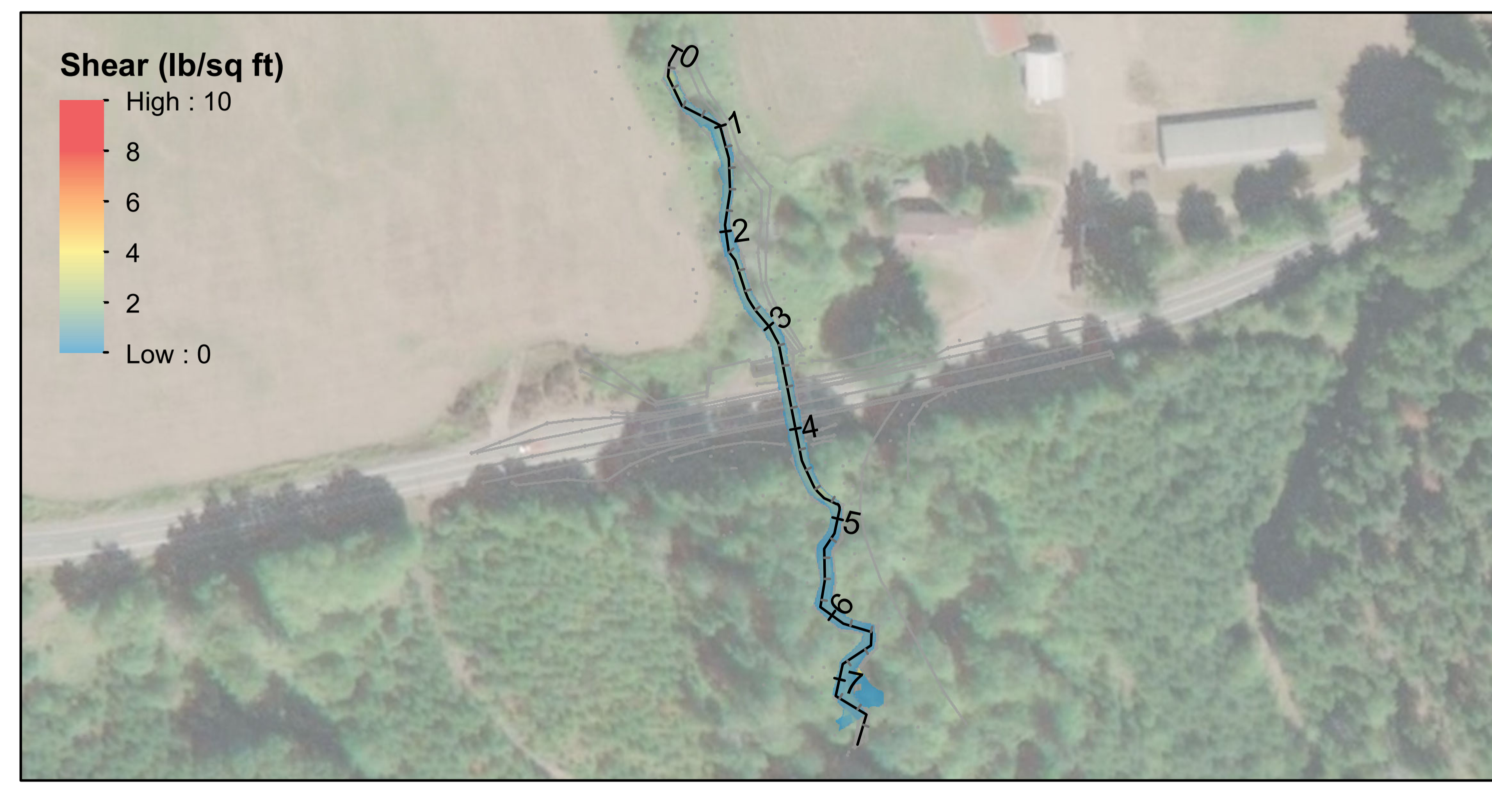

SHEAR

N

0 100 200 Feet

Washington State Department of Transportation

PROPOSED CONDITIONS - 2 YEAR EVENT

SR 108 MCDONALD CREEK
MP 8.89

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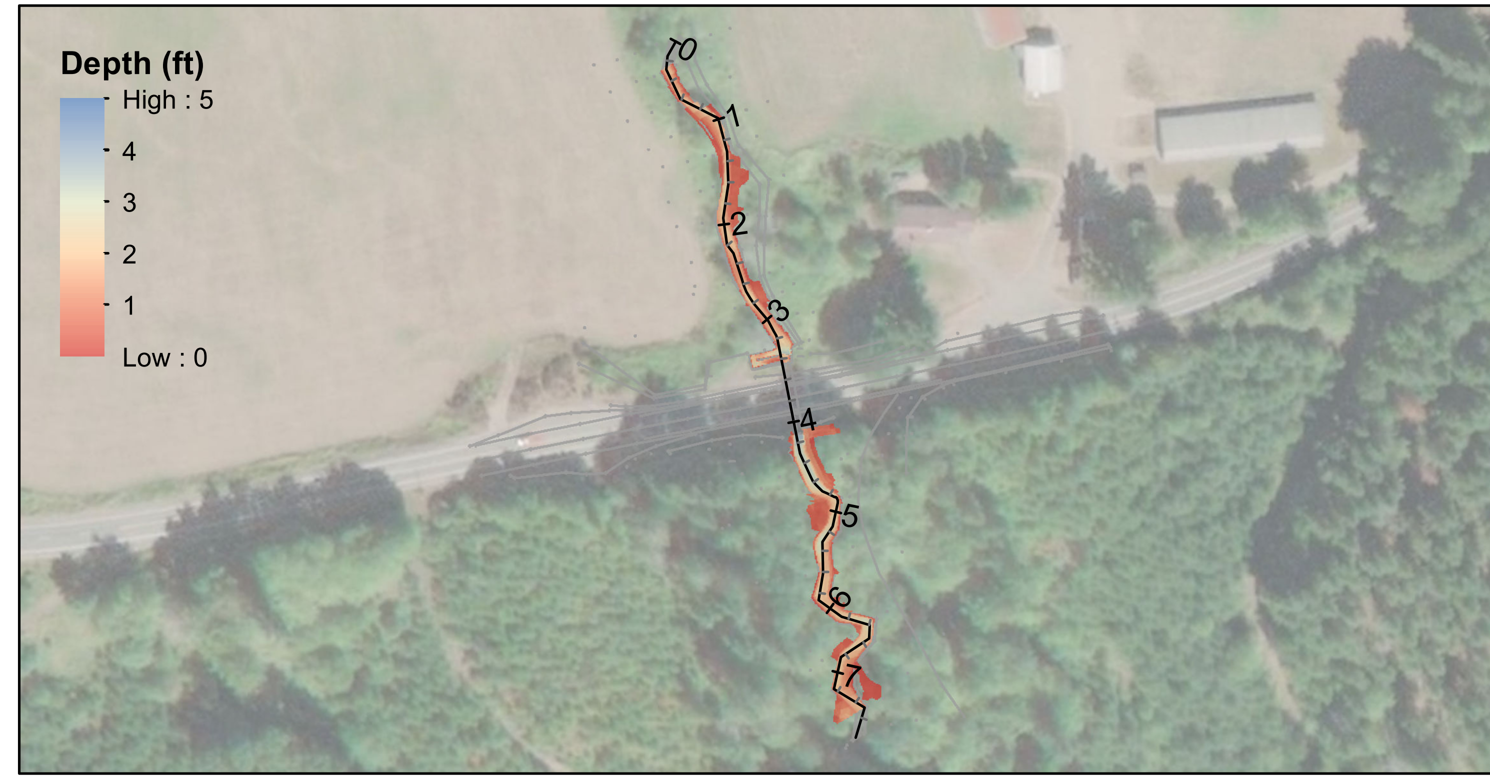
PRELIMINARY HYDARULIC DESIGN

WATER SURFACE ELEVATION



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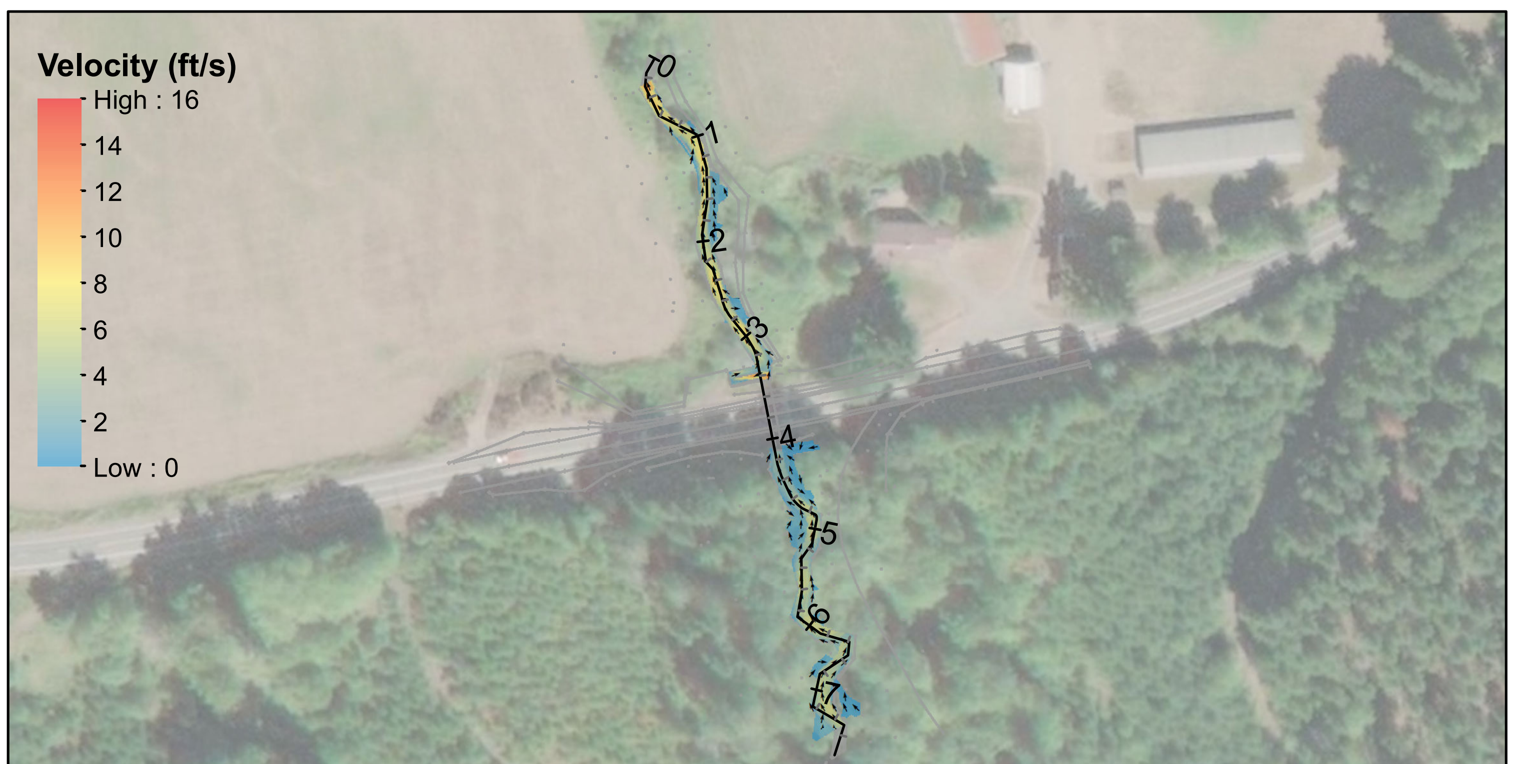

VELOCITY

SHEAR

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0 100 200 Feet

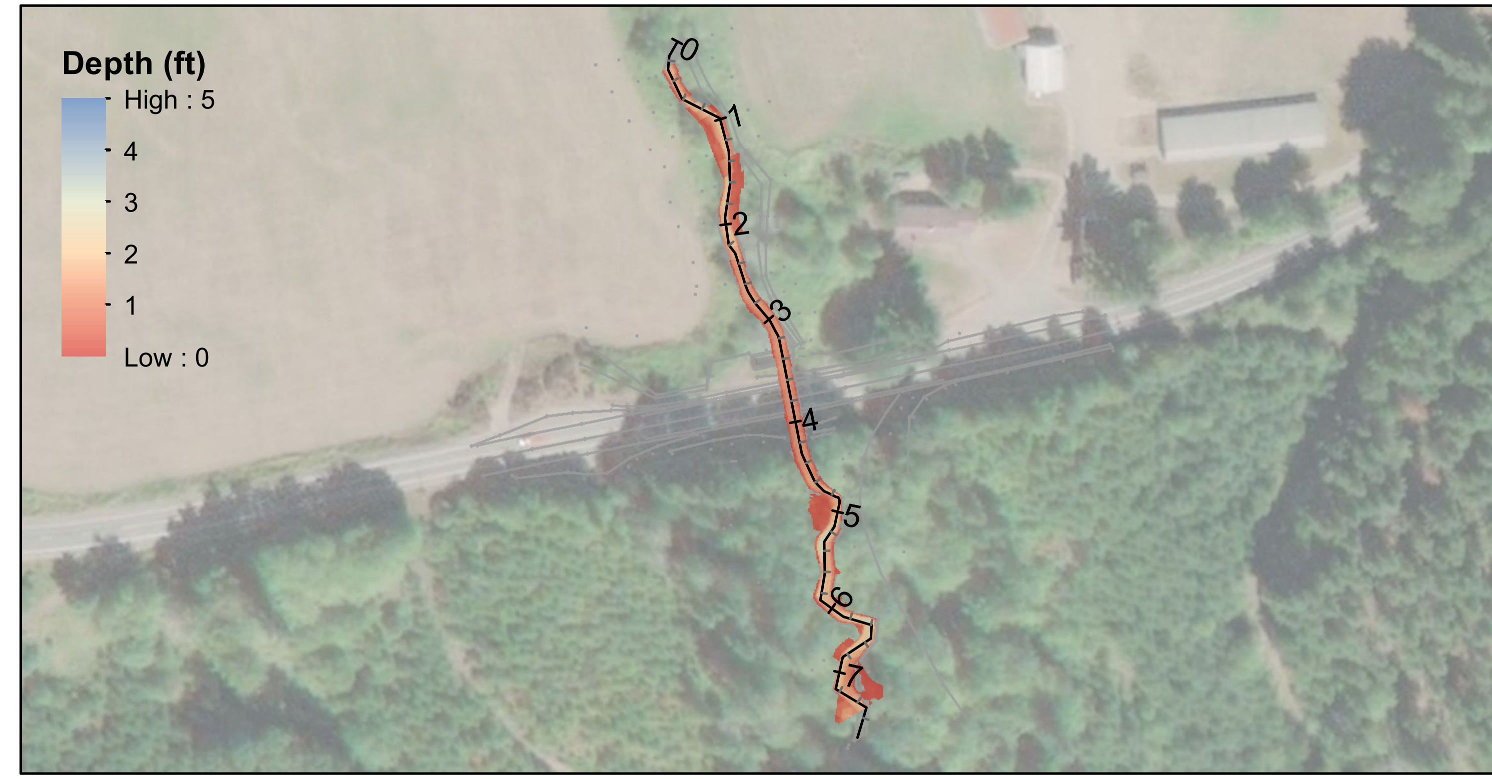
HDR

Washington State Department of Transportation

EXISTING CONDITIONS - 25 YEAR EVENT

SR 108 MCDONALD CREEK
MP 8.89

WATER SURFACE ELEVATION



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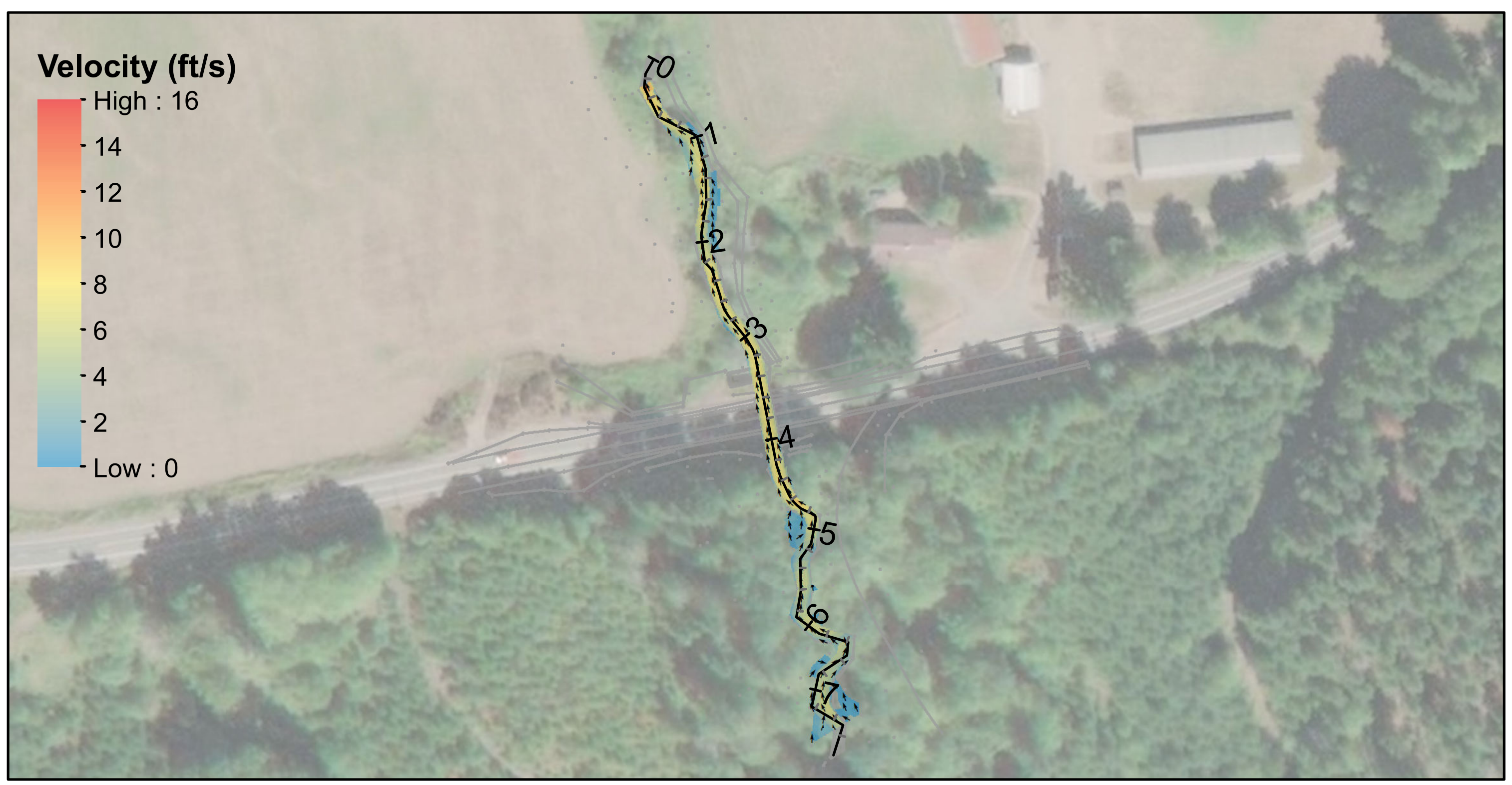

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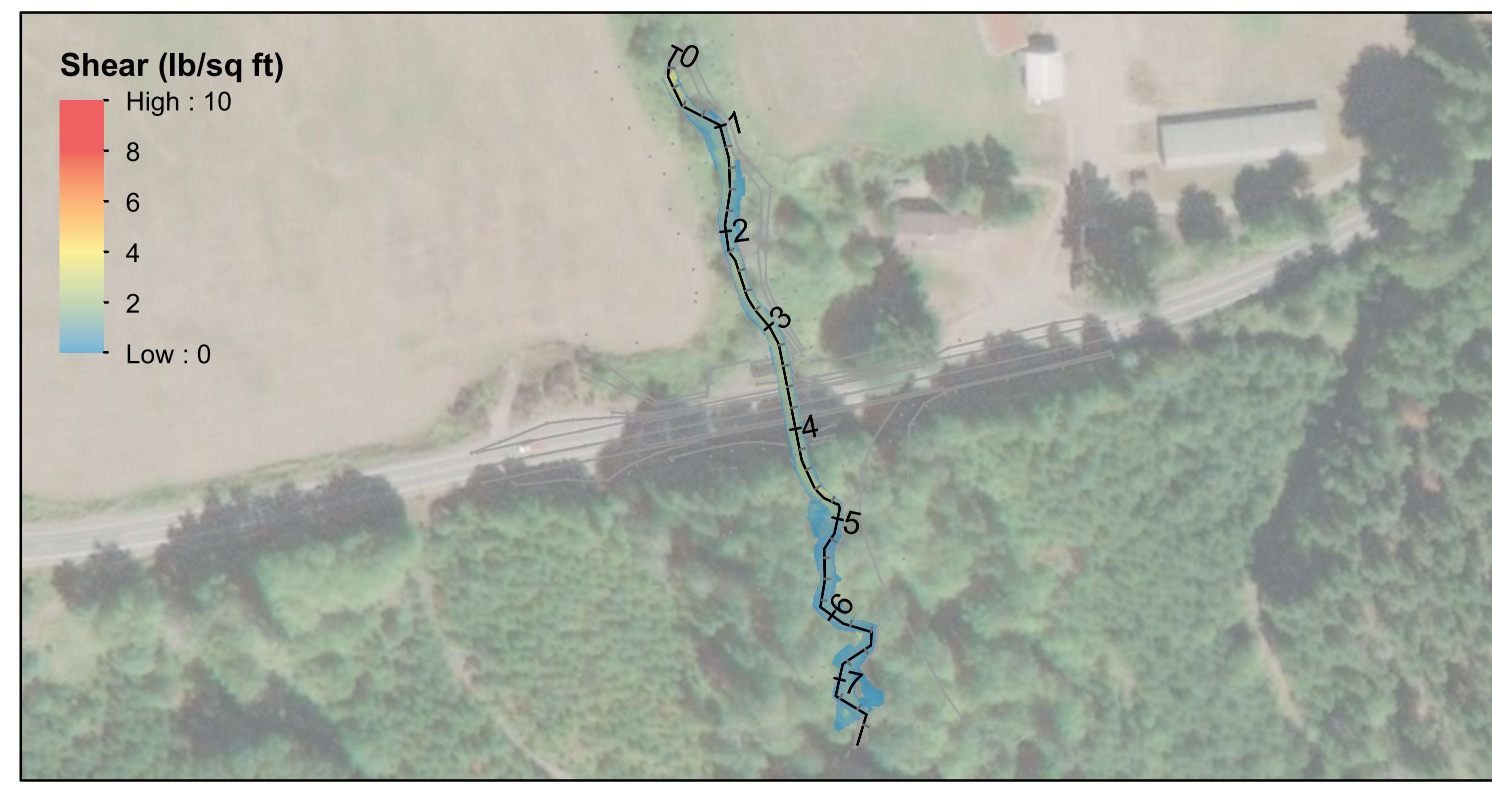

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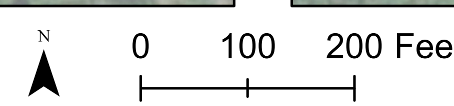

Washington State Department of Transportation

PROPOSED CONDITIONS - 25 YEAR EVENT

SR 108 MCDONALD CREEK
MP 8.89

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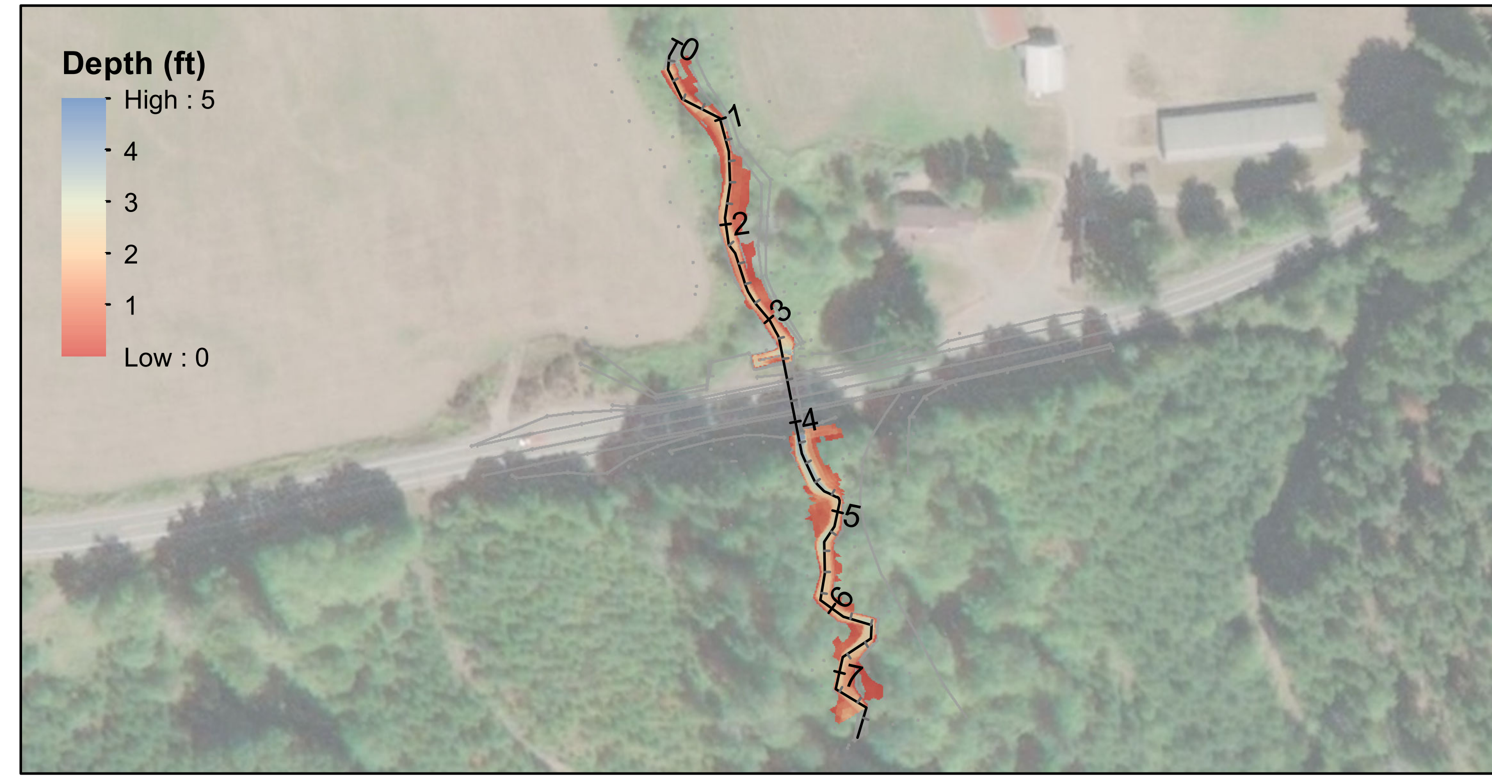
PRELIMINARY HYDARULIC DESIGN

WATER SURFACE ELEVATION



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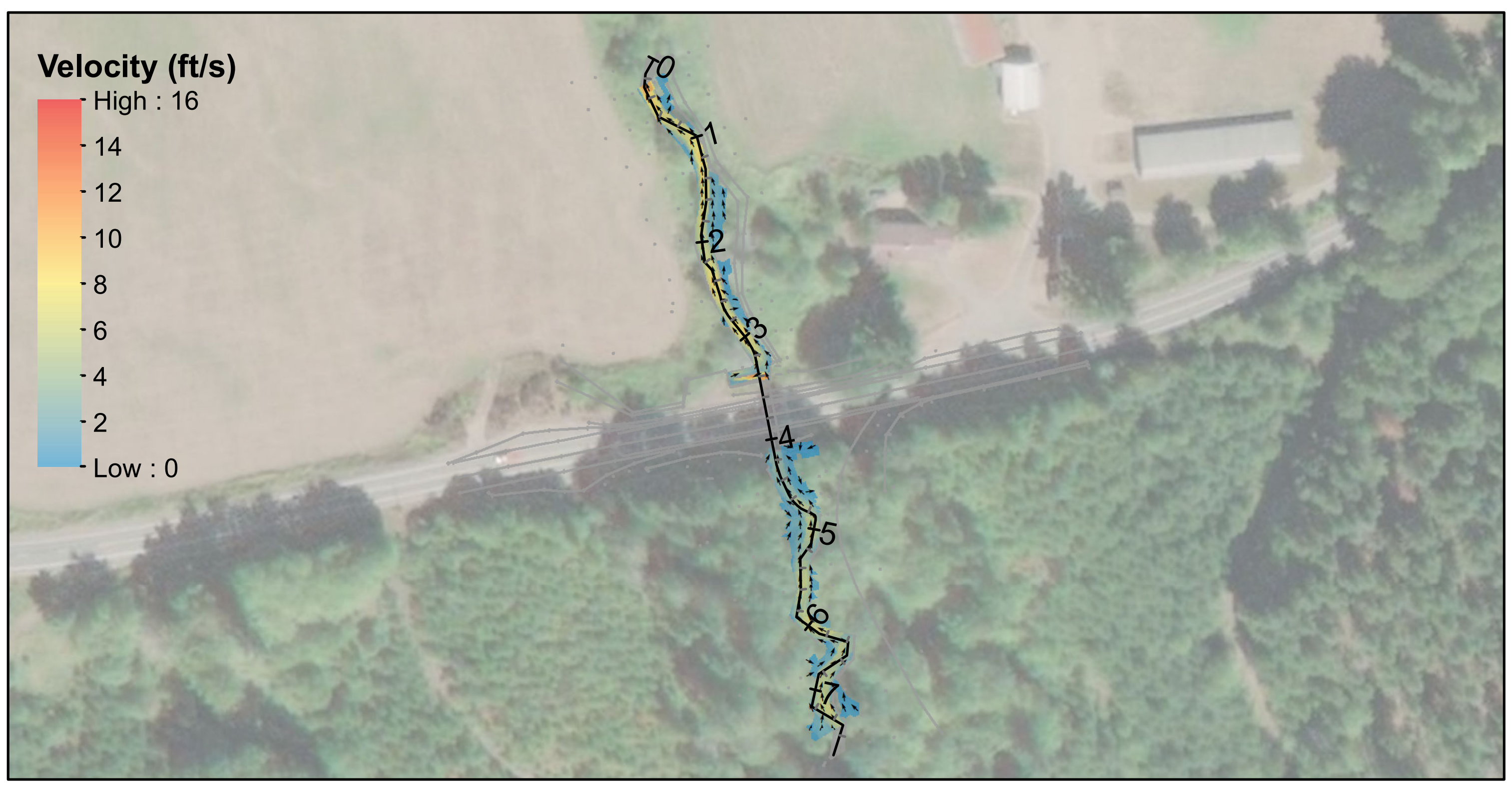

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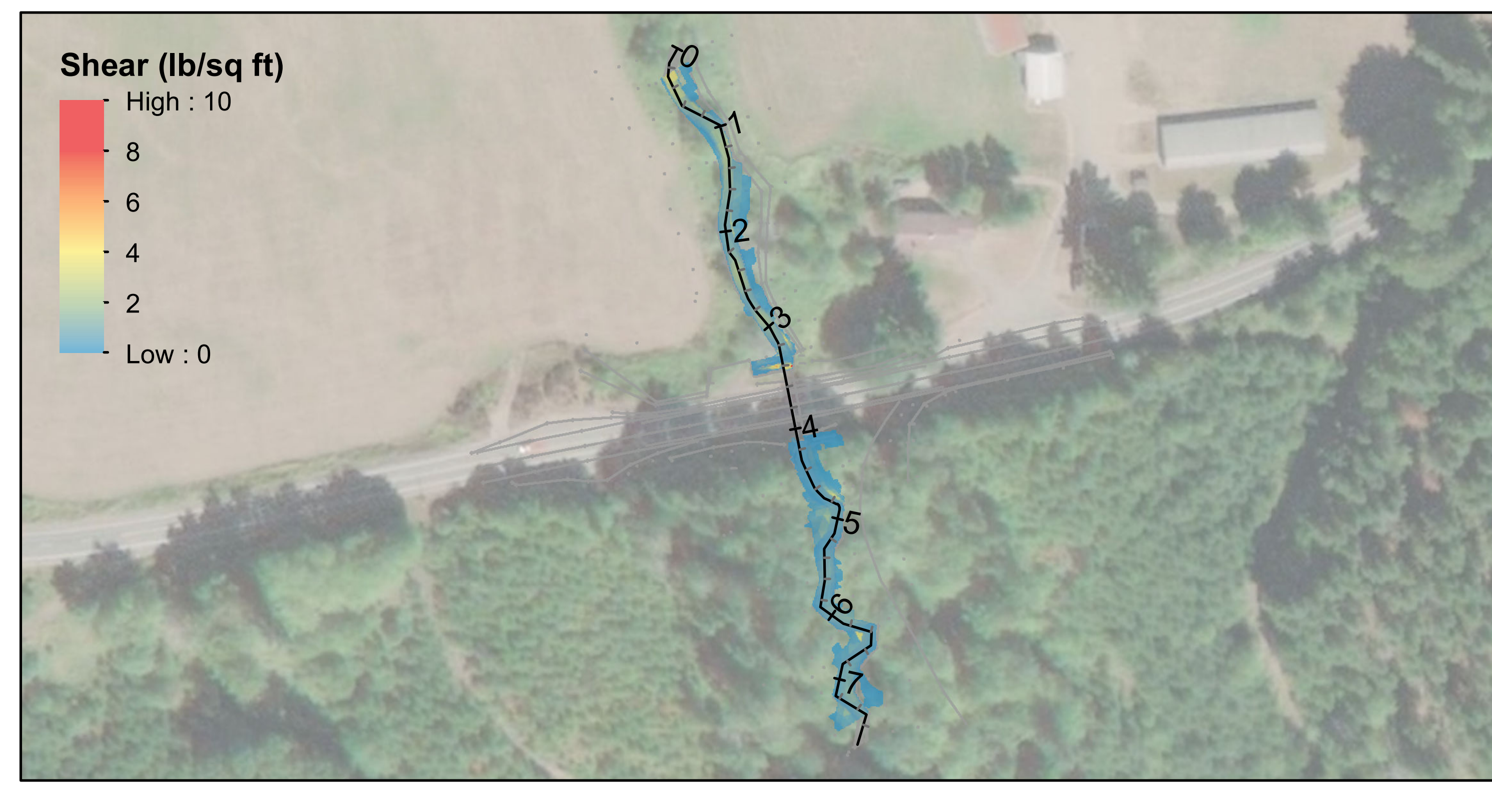


SHEAR

N

0 100 200 Feet

HDR

Washington State Department of Transportation

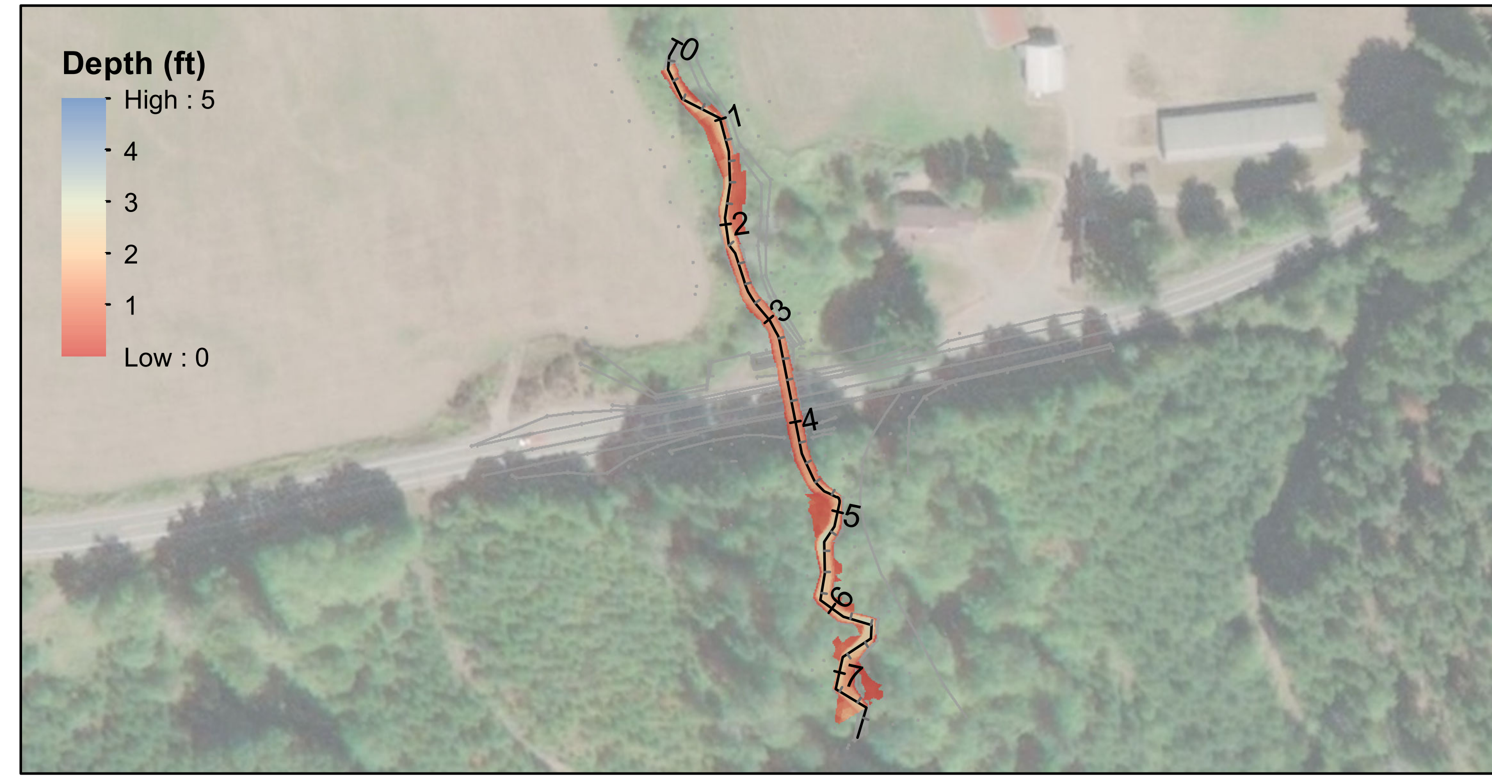
EXISTING CONDITIONS - 50 YEAR EVENT

SR 108 MCDONALD CREEK
MP 8.89

PATH: S:\SR108\MP8.89 WDFW ID 990278 MCDONALD CREEK\SRH2D\RESULTS\OUTPUT FIGURES\EXISTING_50YR FINAL.MXD - USER: DMINNER - DATE: 10/1/2019

PRELIMINARY HYDARULIC DESIGN

WATER SURFACE ELEVATION



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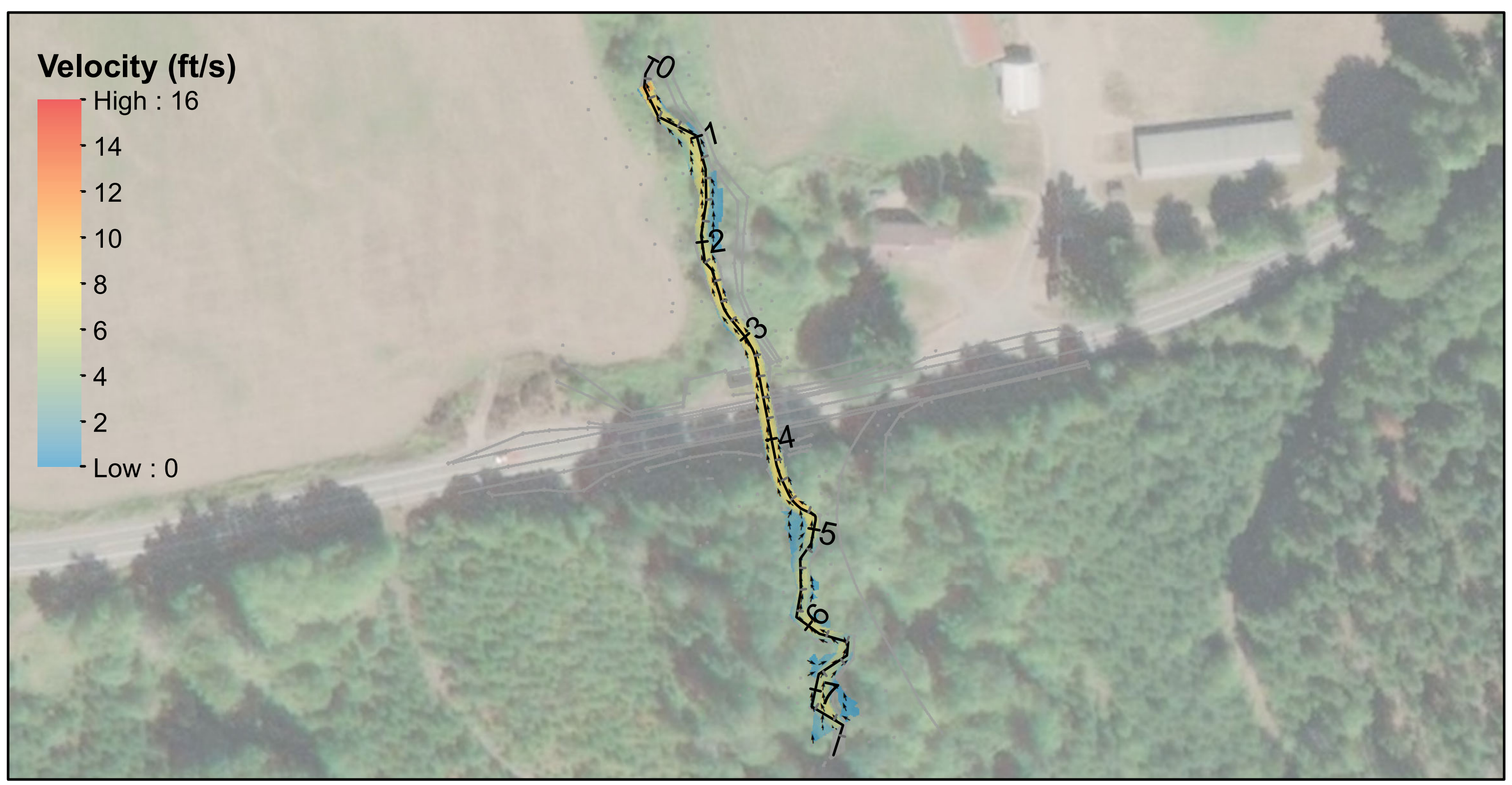

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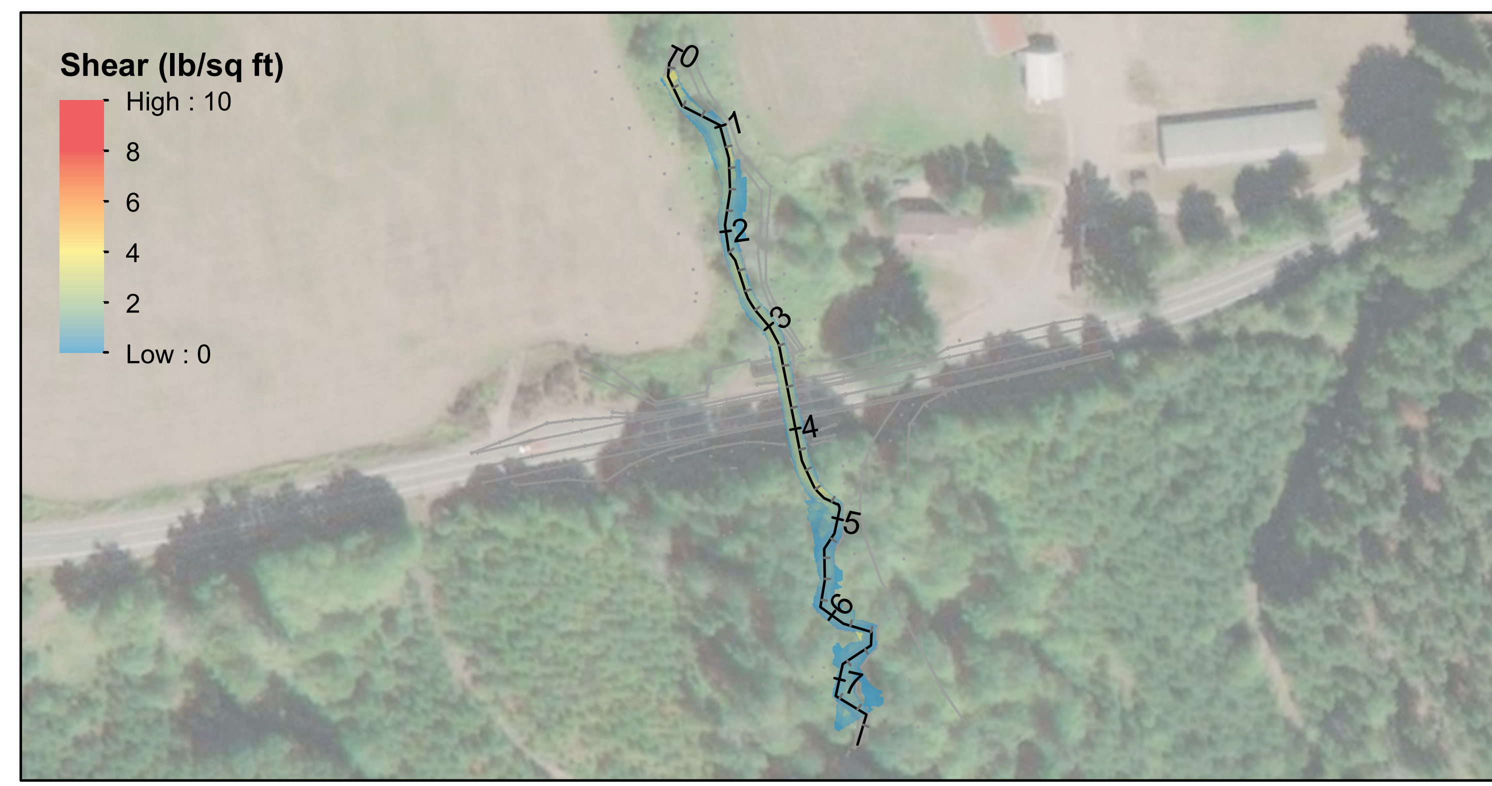


SHEAR

N

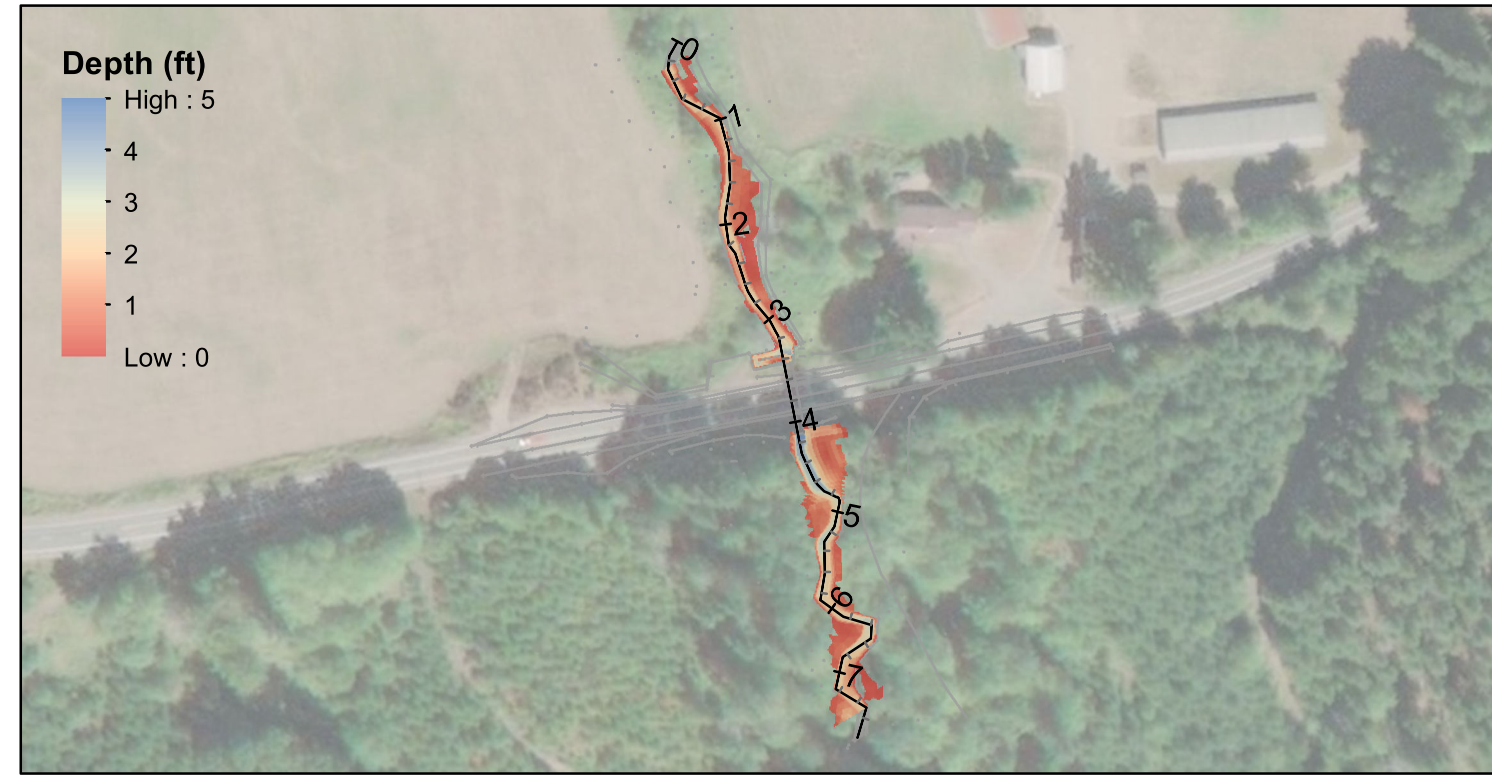
0 100 200 Feet

Washington State Department of Transportation

PROPOSED CONDITIONS - 50 YEAR EVENT

SR 108 MCDONALD CREEK
MP 8.89

WATER SURFACE ELEVATION



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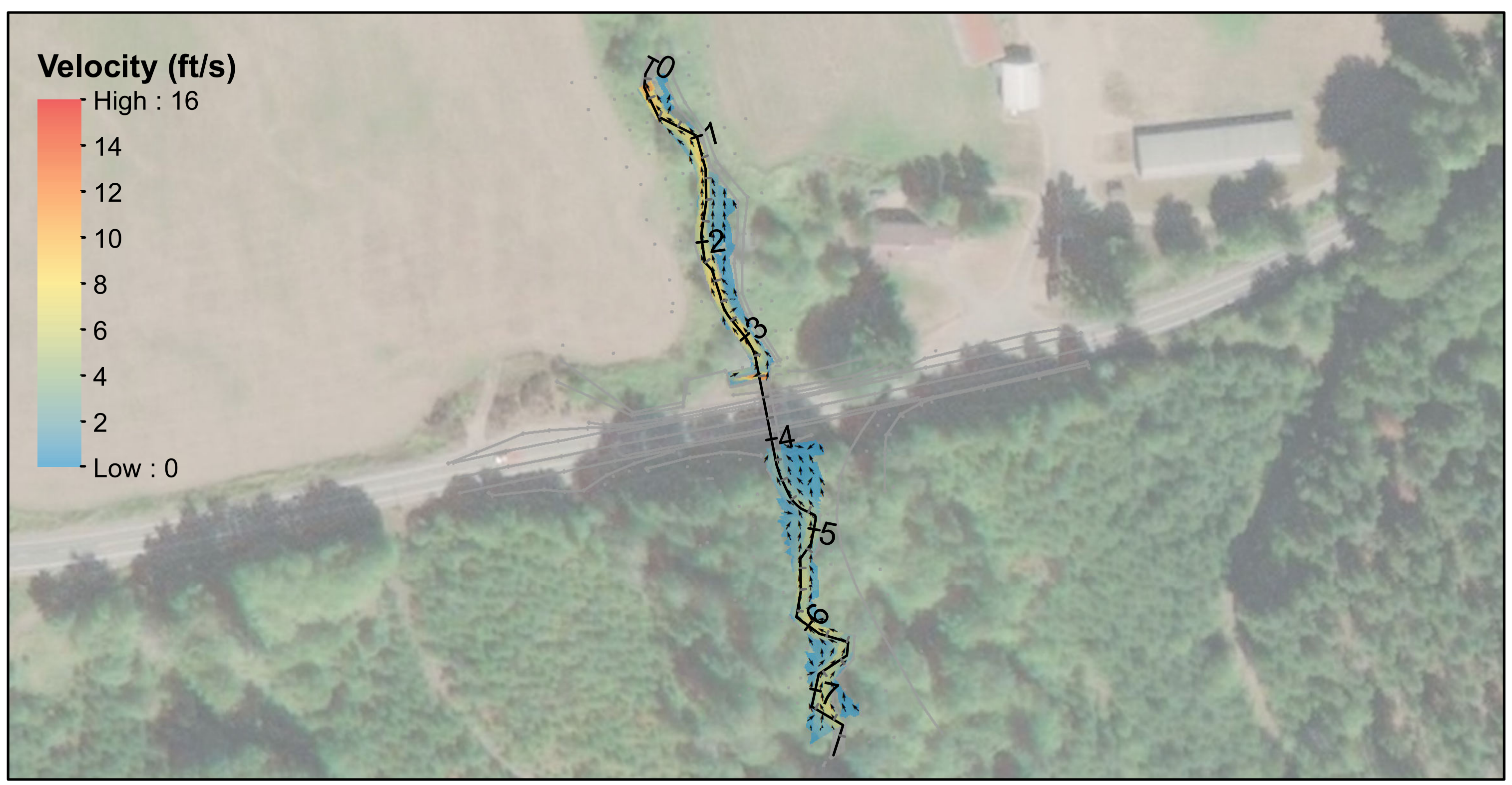

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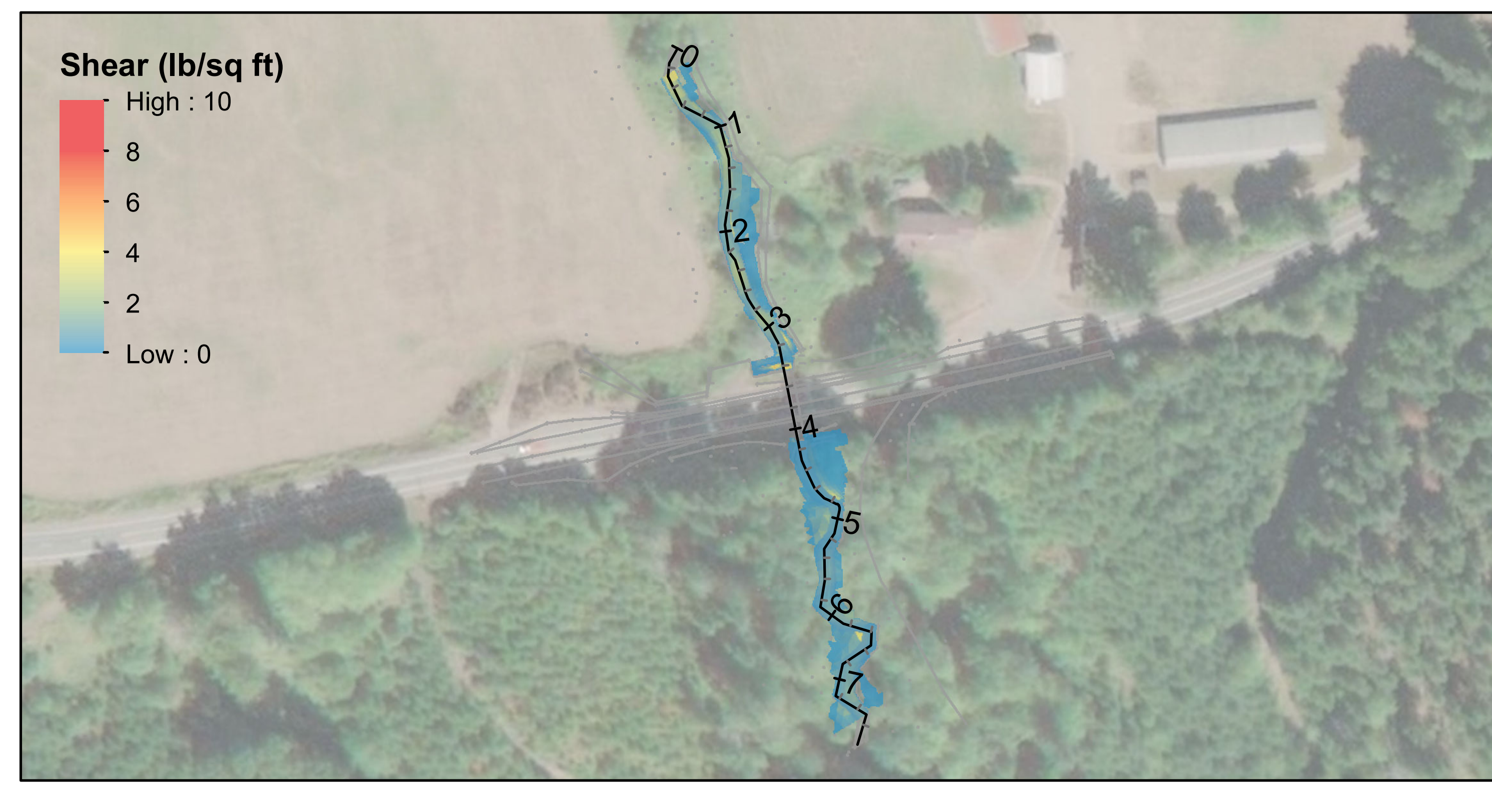


SHEAR

N

0 100 200 Feet

Washington State
Department of Transportation

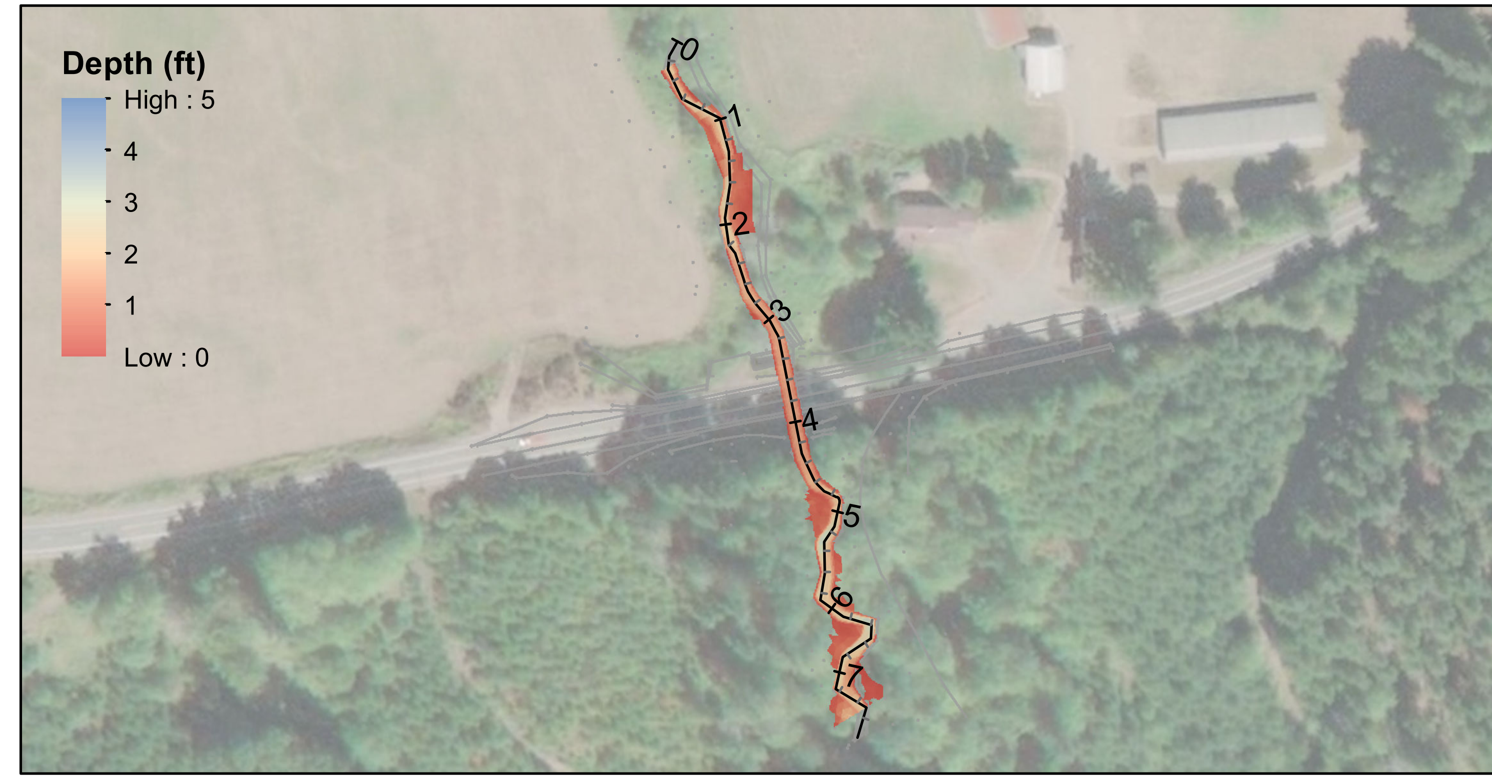
EXISTING CONDITIONS - 100 YEAR EVENT

SR 108 MCDONALD CREEK
MP 8.89

PATH: S:\SR108\MP8.89 WDFW ID 990278 MCDONALD CREEK\SRH2D\RESULTS\OUTPUT FIGURES\EXISTING_100YR FINAL.MXD - USER: DMINNER - DATE: 10/1/2019

PRELIMINARY HYDARULIC DESIGN

WATER SURFACE ELEVATION



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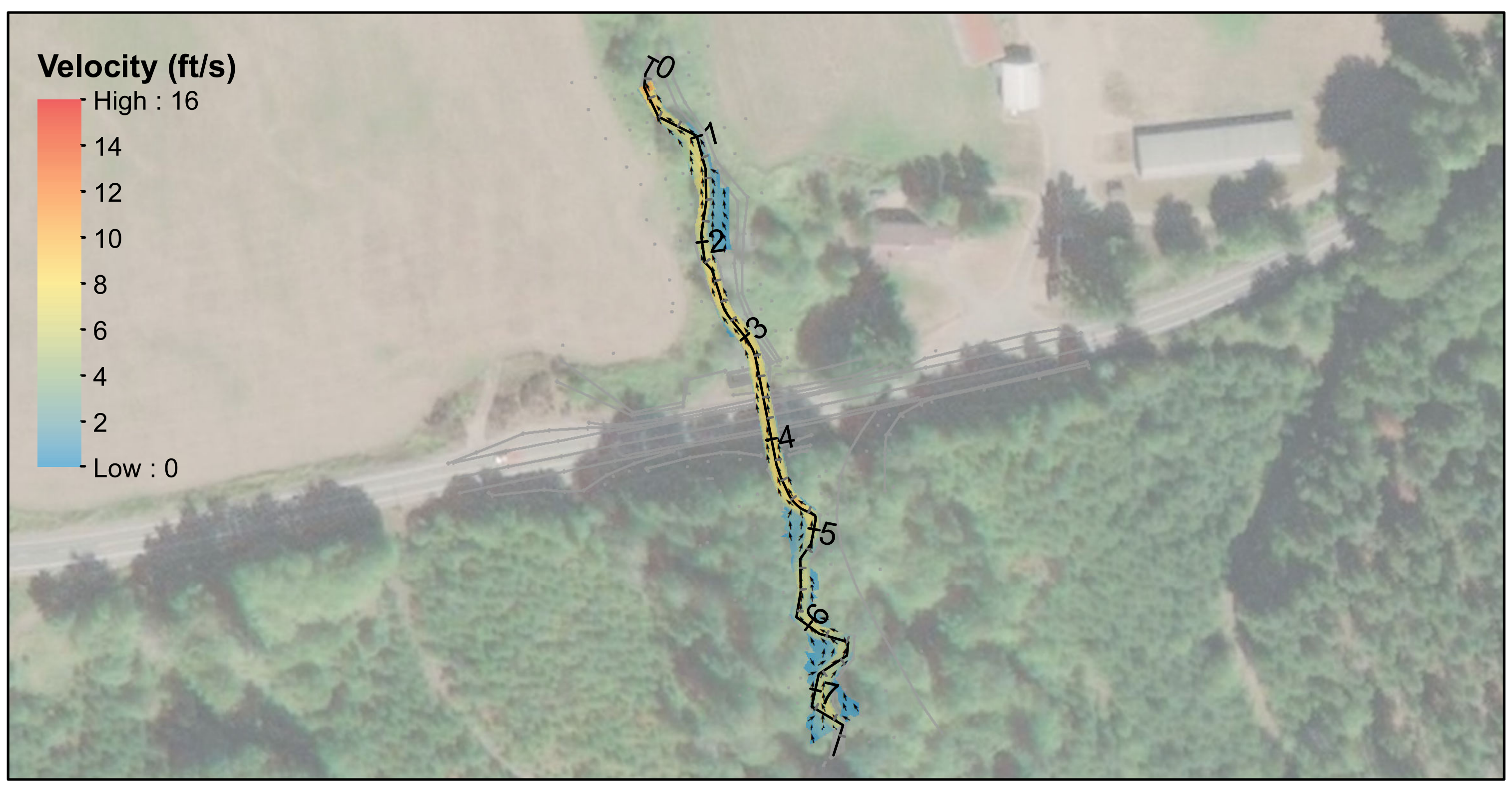

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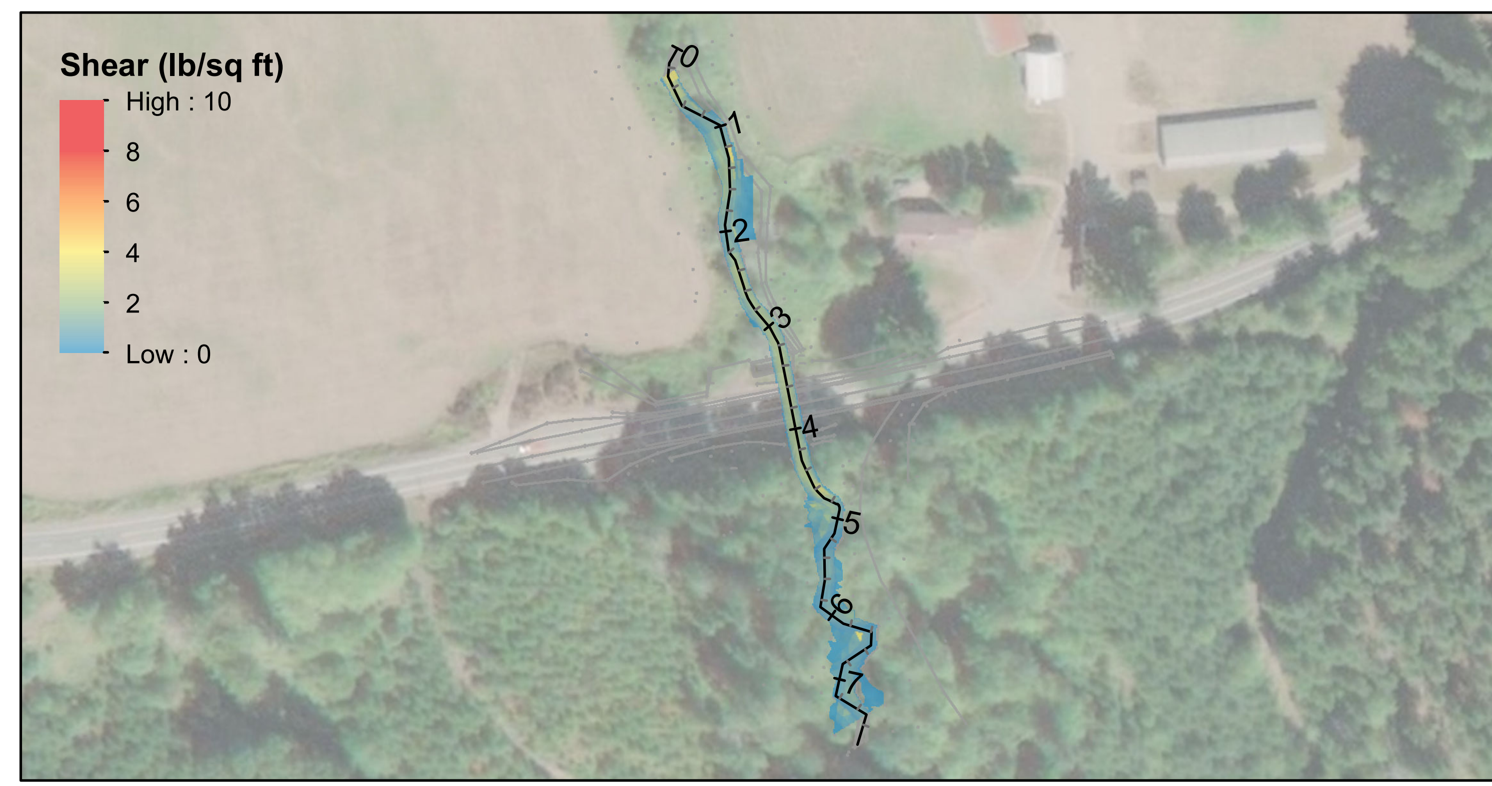


SHEAR

N

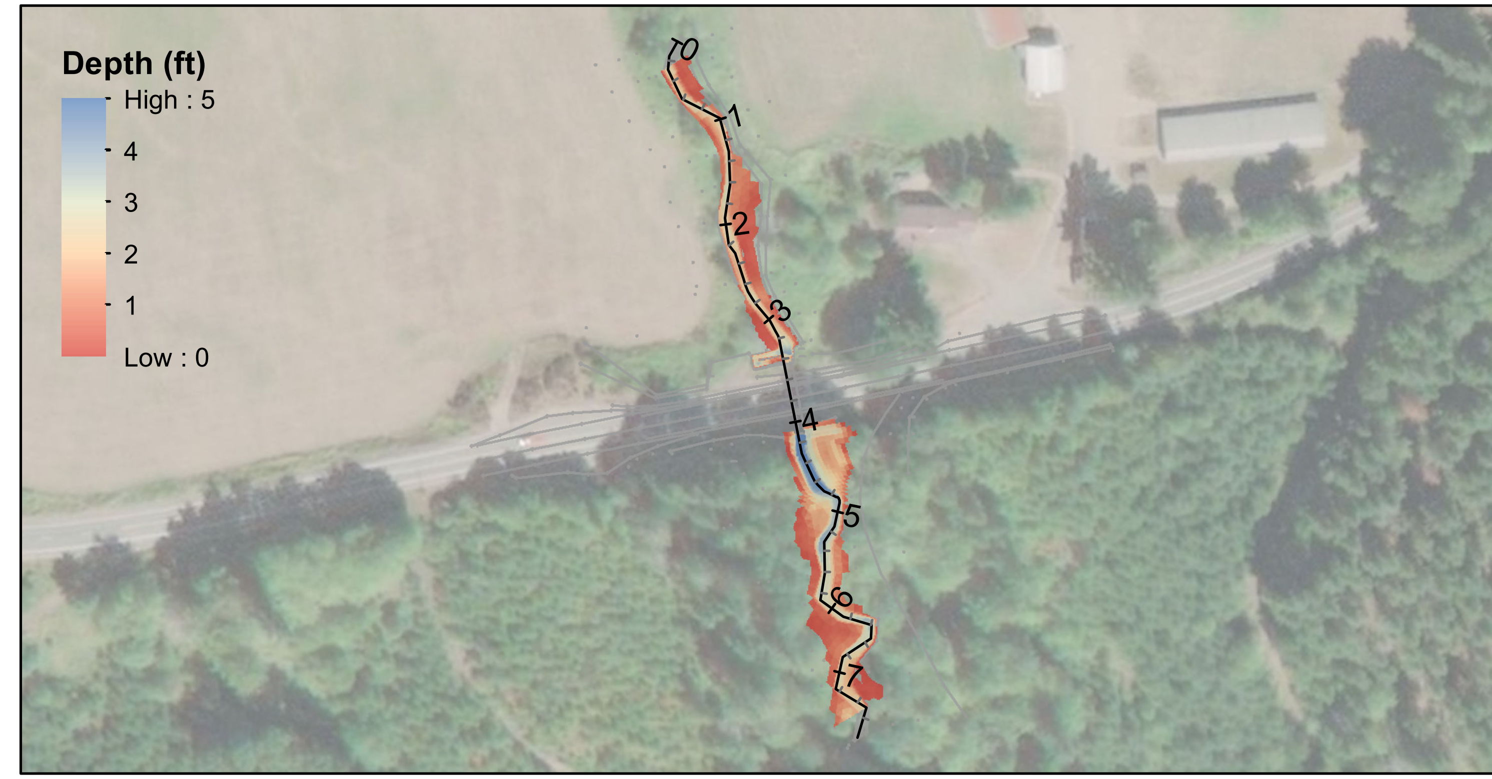
0 100 200 Feet

Washington State Department of Transportation

PROPOSED CONDITIONS - 100 YEAR EVENT

SR 108 MCDONALD CREEK
MP 8.89

WATER SURFACE ELEVATION



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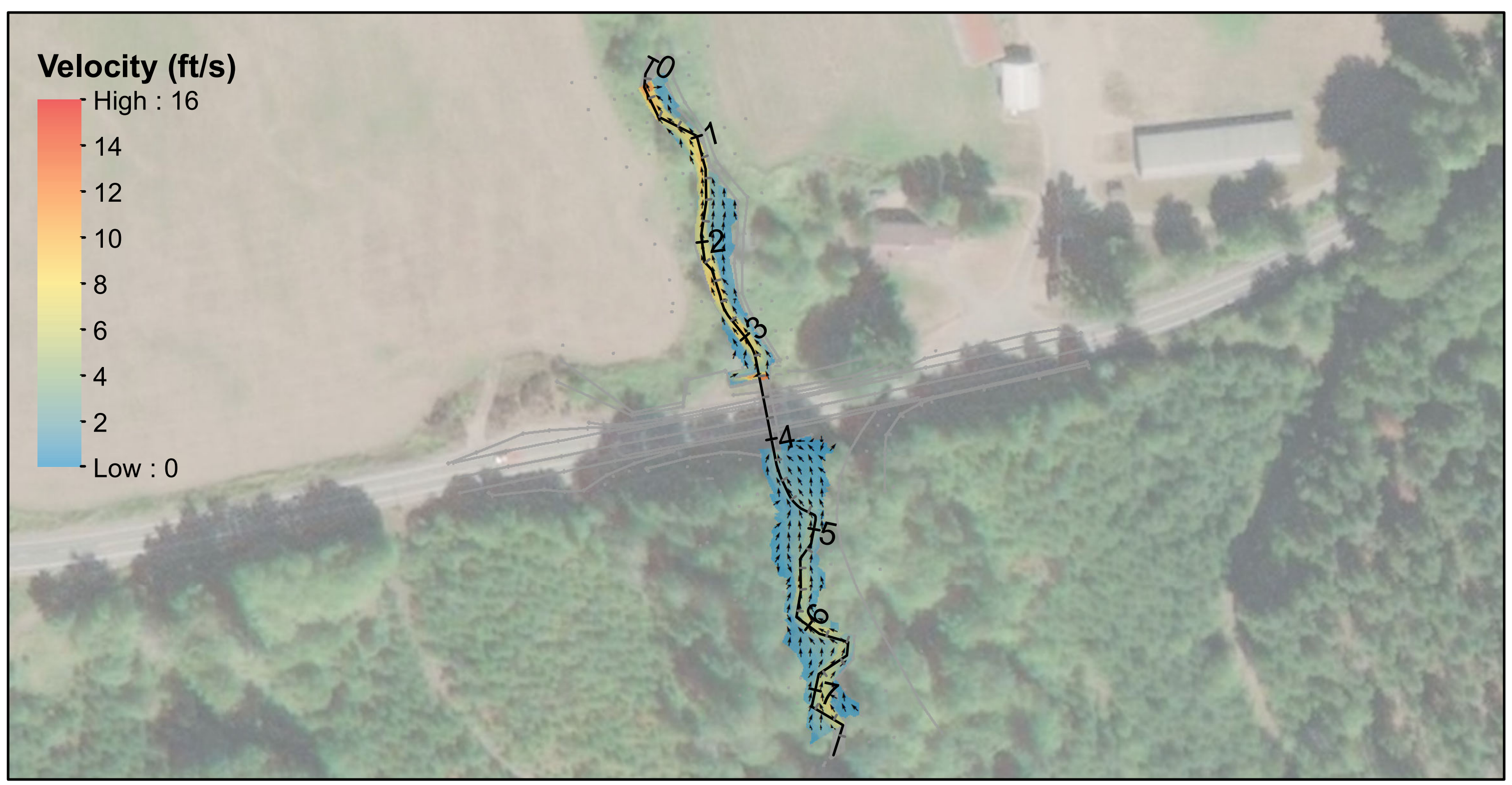

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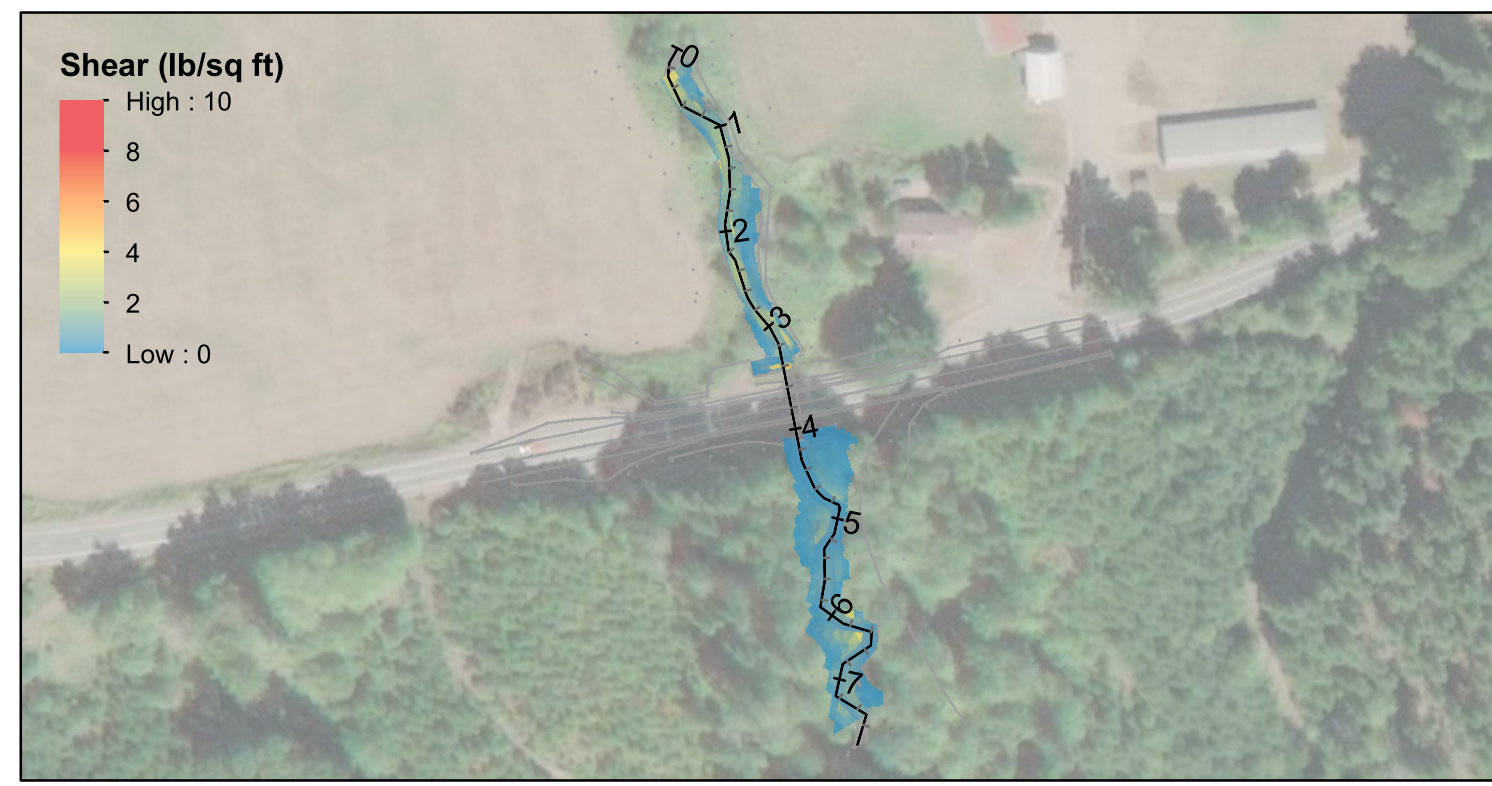


SHEAR

N

0 100 200 Feet

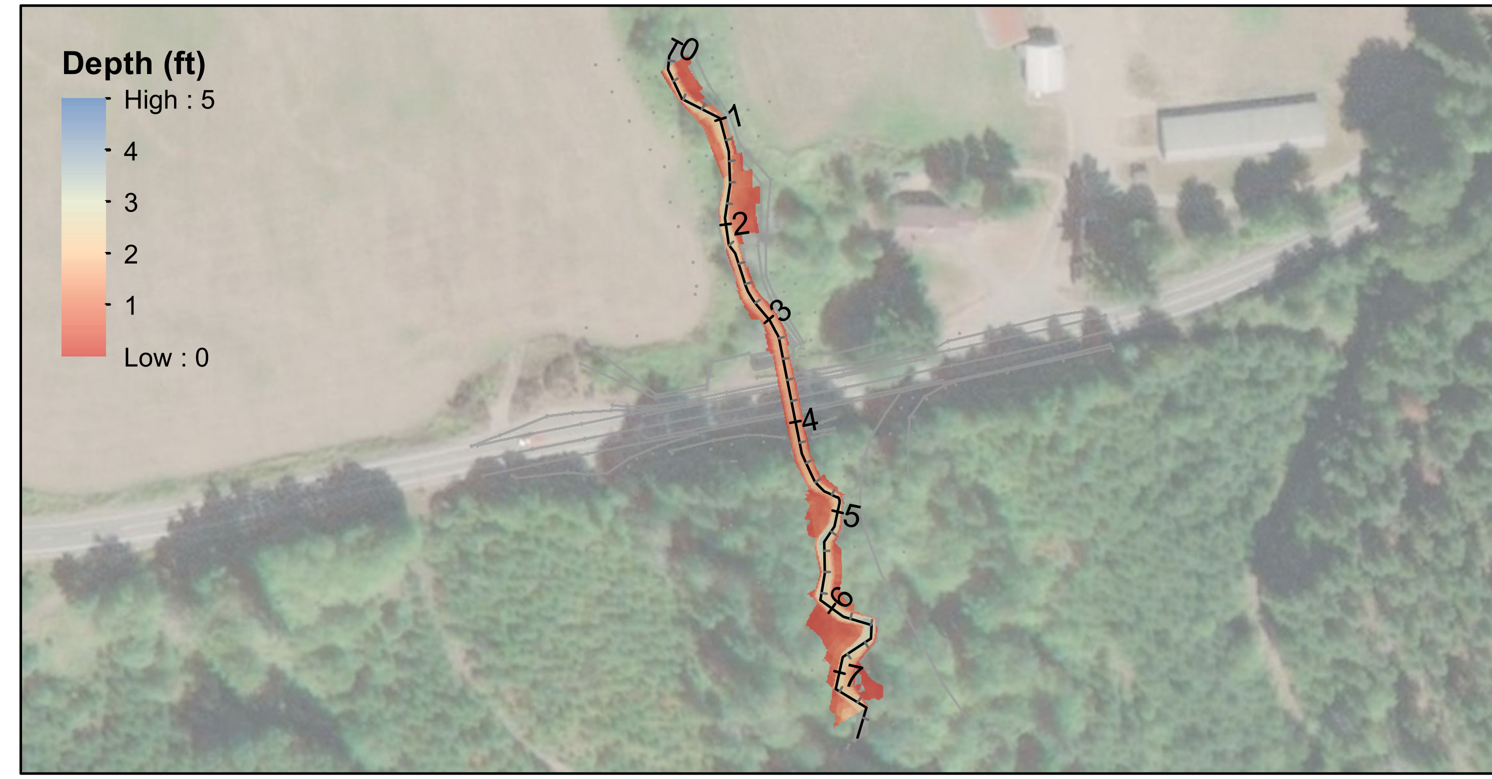
HDR

Washington State Department of Transportation

EXISTING CONDITIONS - 500 YEAR EVENT

SR 108 MCDONALD CREEK
MP 8.89

WATER SURFACE ELEVATION



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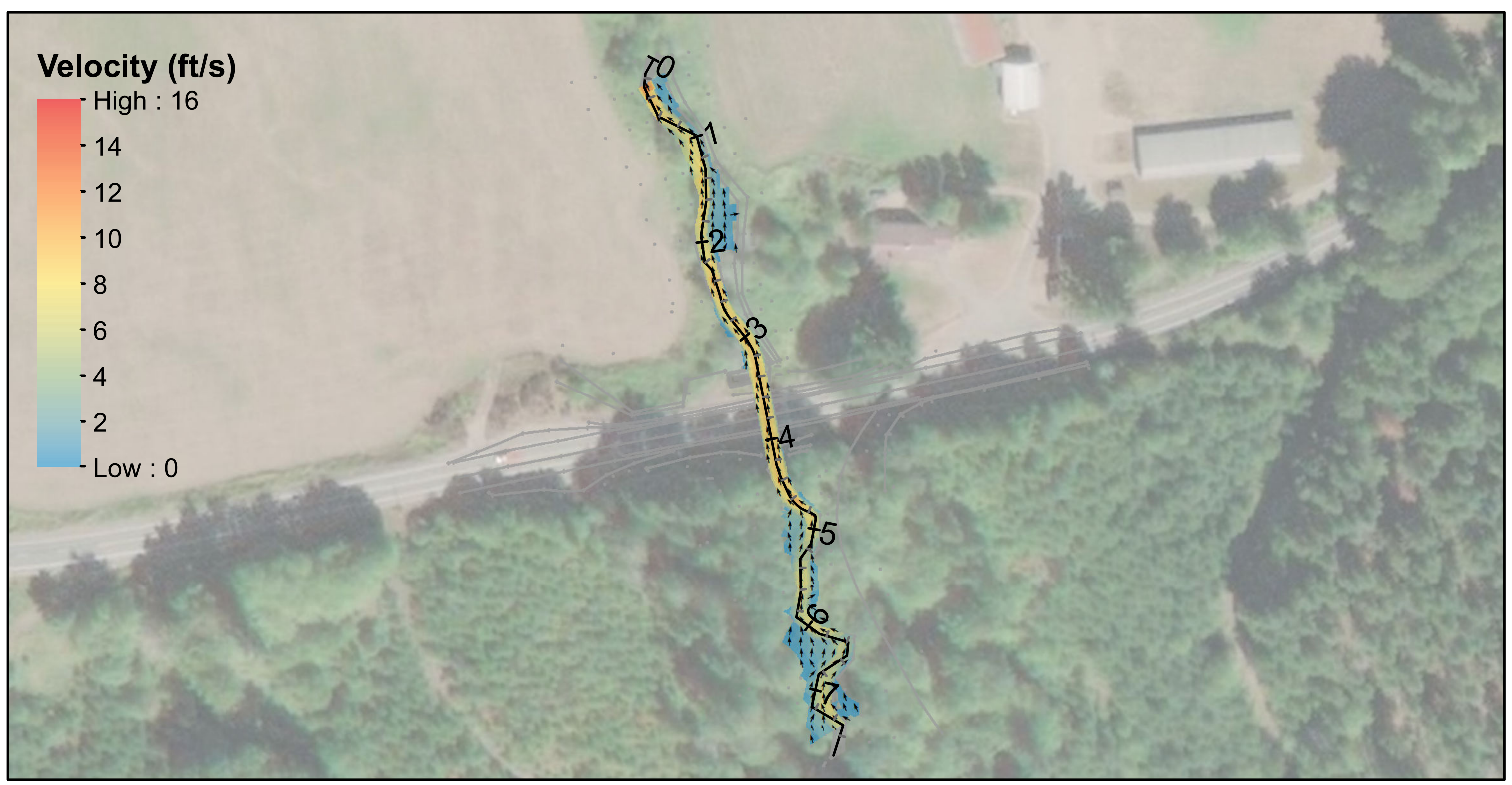

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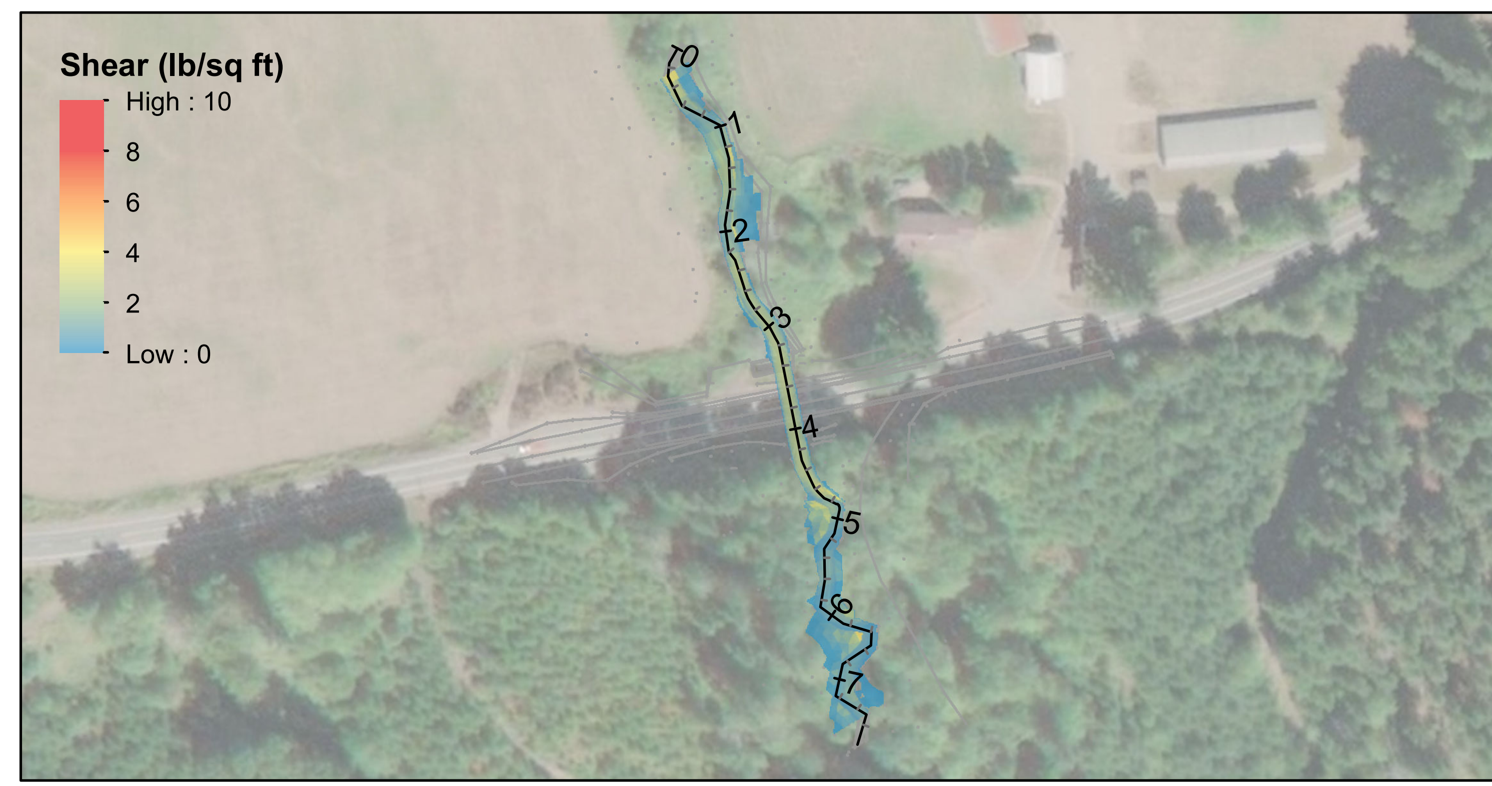


SHEAR

N

0 100 200 Feet

HDR

Washington State Department of Transportation

PROPOSED CONDITIONS - 500 YEAR EVENT

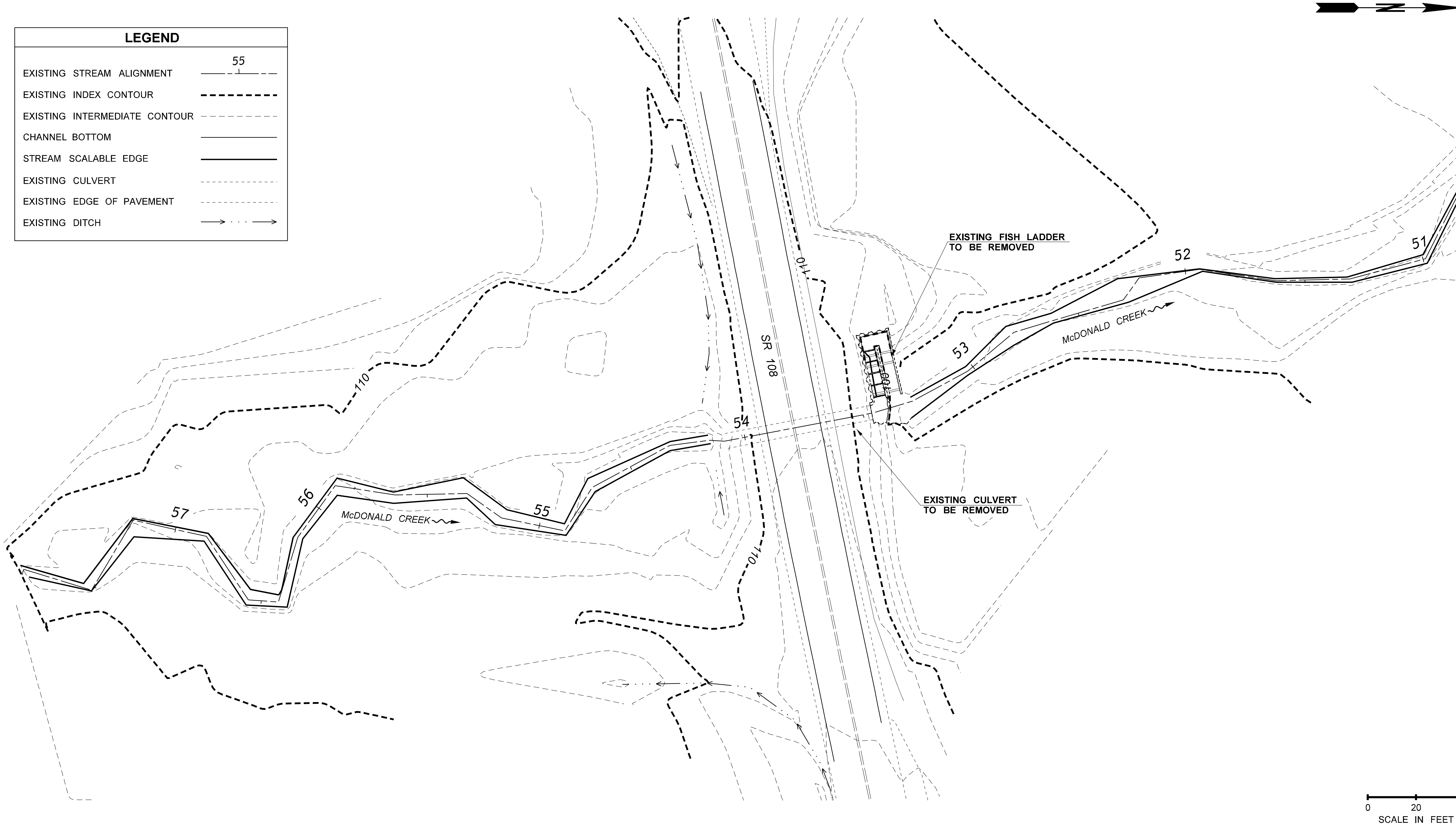
SR 108 MCDONALD CREEK
MP 8.89

PATH: S:\SR108\MP8.89 WDFW ID 990278 MCDONALD CREEK\SRH2D\RESULTS\OUTPUT FIGURES\PROPOSED_500YR FINAL.MXD - USER: DMINNER - DATE: 10/1/2019

PRELIMINARY HYDARULIC DESIGN

Appendix B – Stream Plan Sheets, Profile, Details

T.19N. R.4W. W.M.



PRELIMINARY - NOT FOR CONSTRUCTION

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DESIGNED BY	S. BEVAN			
ENTERED BY	C. WILCOX			
CHECKED BY	J. HEILMAN			
PROJ. ENGR.	J. METTLER			
REGIONAL ADM.	J WYNANDS	REVISION	DATE	BY

REGION NO.	STATE	FED.AID PROJ.NO.
10	WASH	
JOB NUMBER XXXXX		
CONTRACT NO.		LOCATION NO. XL5950

P.E. STAMP BOX DATE

P.E. STAMP BOX DATE

Washington State Department of Transportation

HDR

SR 108
MP 8.89
McDONALD CREEK

EXISTING STREAM PLAN

PLAN REF NO CE1

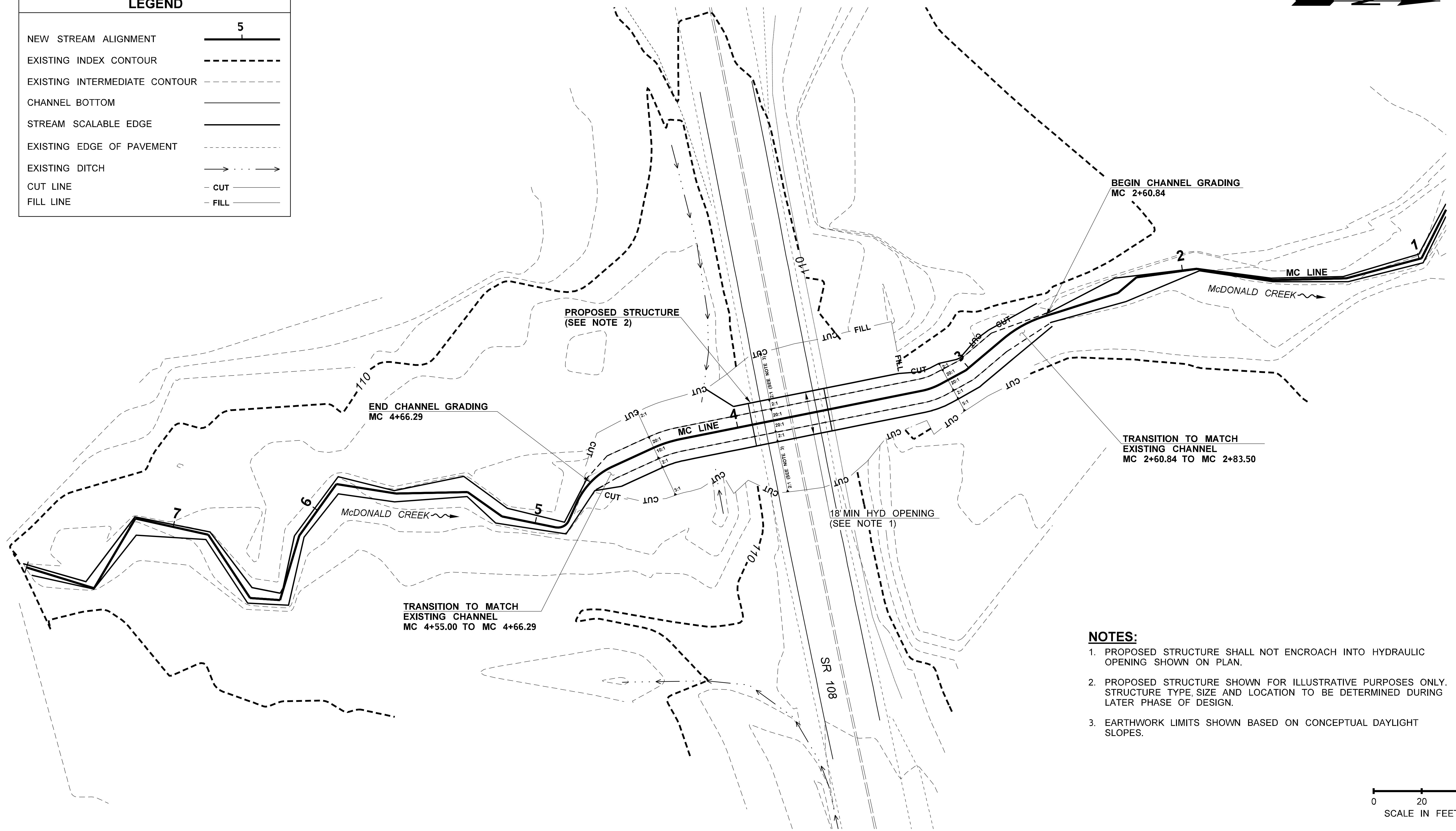
SHEET 1 OF 4 SHEETS

pw:\\HQOLYMAPPPW03P.WSDOT.LOC:WSDOT\Documents_HQ\Fish Passage\ORproj\108\8.89_McDonaldCreek\Hydraulics_CAD_Sheets\StreamPlanProfDetails\XL5950_PS_CE_001

T.19N. R.4W. W.M.

LEGEND

NEW STREAM ALIGNMENT	5
EXISTING INDEX CONTOUR	
EXISTING INTERMEDIATE CONTOUR	
CHANNEL BOTTOM	
STREAM SCALABLE EDGE	
EXISTING EDGE OF PAVEMENT	
EXISTING DITCH	
CUT LINE	CUT
FILL LINE	FILL



NOTES:

1. PROPOSED STRUCTURE SHALL NOT ENCROACH INTO HYDRAULIC OPENING SHOWN ON PLAN.
2. PROPOSED STRUCTURE SHOWN FOR ILLUSTRATIVE PURPOSES ONLY. STRUCTURE TYPE, SIZE AND LOCATION TO BE DETERMINED DURING LATER PHASE OF DESIGN.
3. EARTHWORK LIMITS SHOWN BASED ON CONCEPTUAL DAYLIGHT SLOPES.

PRELIMINARY - NOT FOR CONSTRUCTION

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DATE	10/24/2019
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DESIGNED BY	S. BEVAN
ENTERED BY	C. WILCOX
CHECKED BY	J. HEILMAN
PROJ. ENGR.	J. METTLER
REGIONAL ADM.	J WYNANDS

REVISION	DATE	BY

REGION NO.	STATE	FED.AID PROJ.NO.
10	WASH	
JOB NUMBER XXXXX		
CONTRACT NO.		LOCATION NO. XL5950

P.E. STAMP BOX DATE

P.E. STAMP BOX DATE

Washington State Department of Transportation

HDR

SR 108
MP 8.89
McDONALD CREEK

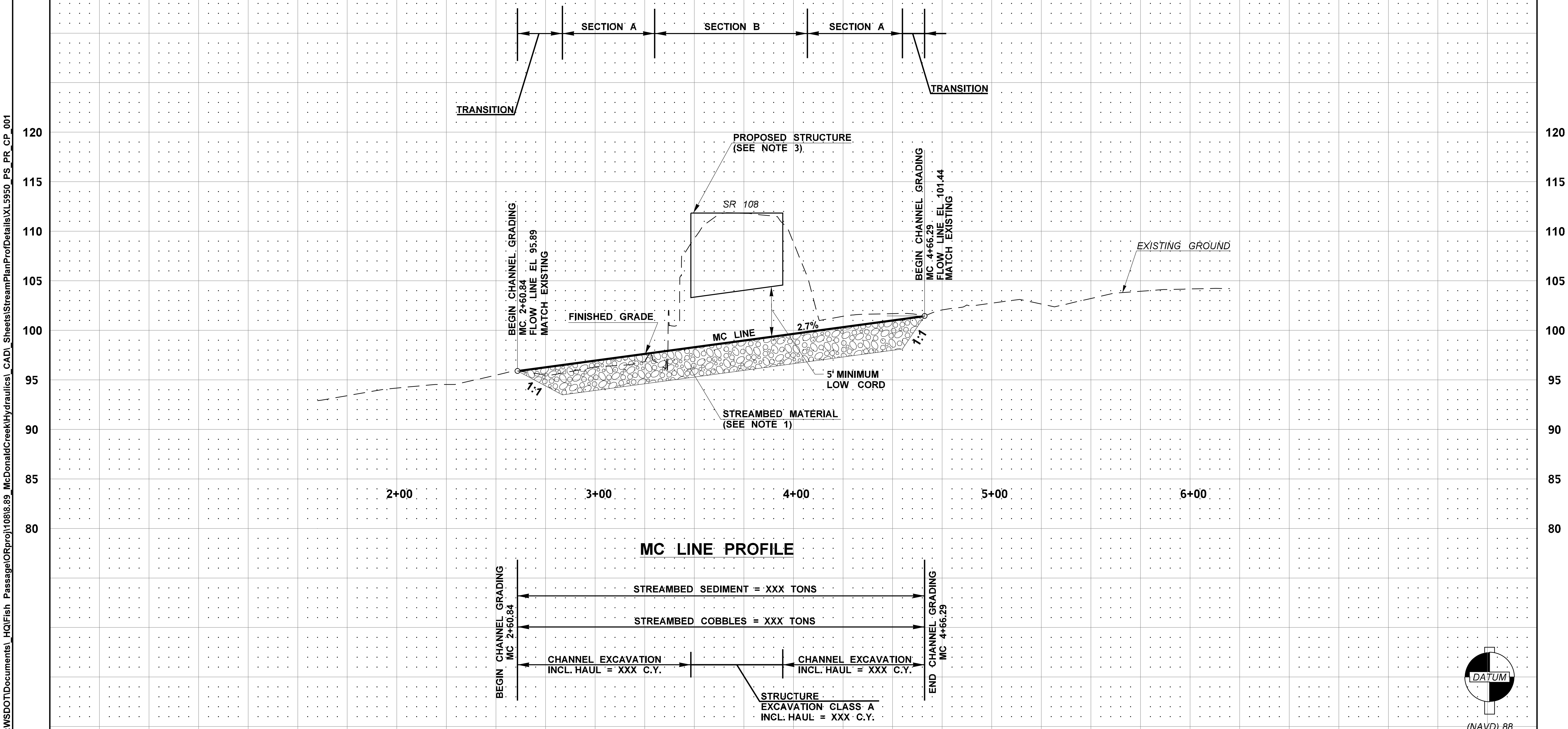
STREAM PLAN

PLAN REF NO CR1

SHEET 2 OF 4 SHEETS

NOTES:

1. SEE SPECIAL PROVISIONS "AGGREGATES FOR STREAMS, RIVERS, AND WATERBODIES FOR STREAMBED MATERIALS.
2. SEE SHEET CD1 FOR STREAM SECTIONS.
3. PROPOSED STRUCTURE SHOWN FOR ILLUSTRATIVE PURPOSES ONLY. STRUCTURE TYPE, SIZE, AND LOCATION TO BE DETERMINED DURING LATER PHASE OF DESIGN.



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ENTERED BY	C. WILCOX
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PROJ. ENGR.	J. METTLER
REGIONAL ADM.	J WYNANDS

REVISION | DATE | BY

REGION NO. 10 | STATE WASH | FED.AID PROJ.NO.

JOB NUMBER XXXXX

CONTRACT NO.

LOCATION NO. XL5950

P.E. STAMP BOX DATE

P.E. STAMP BOX DATE

Washington State Department of Transportation

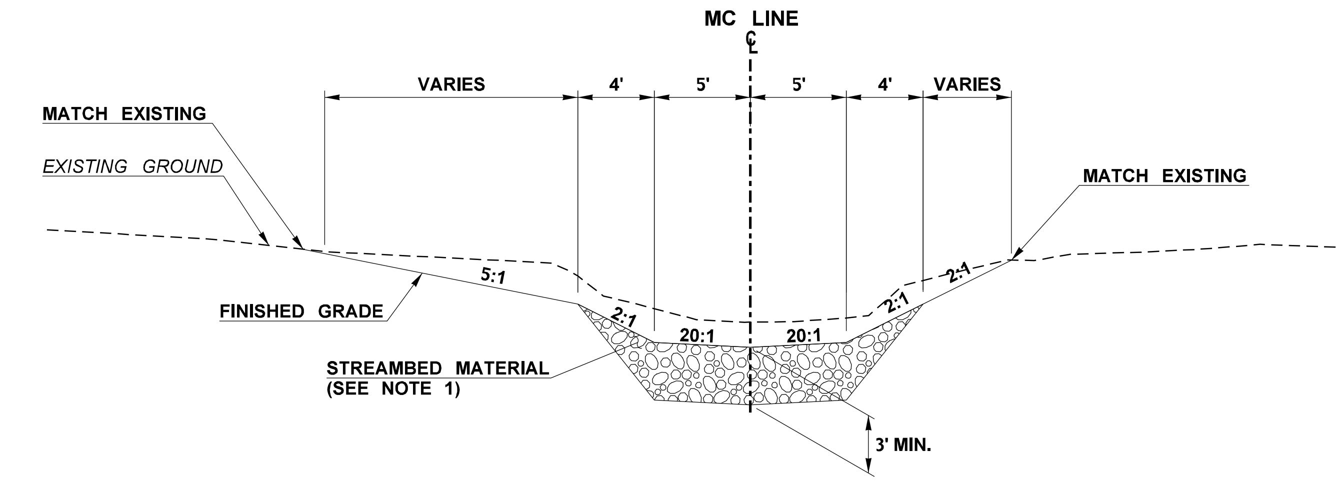
HDR

SR 108
MP 8.89
McDONALD CREEK

STREAM PROFILE

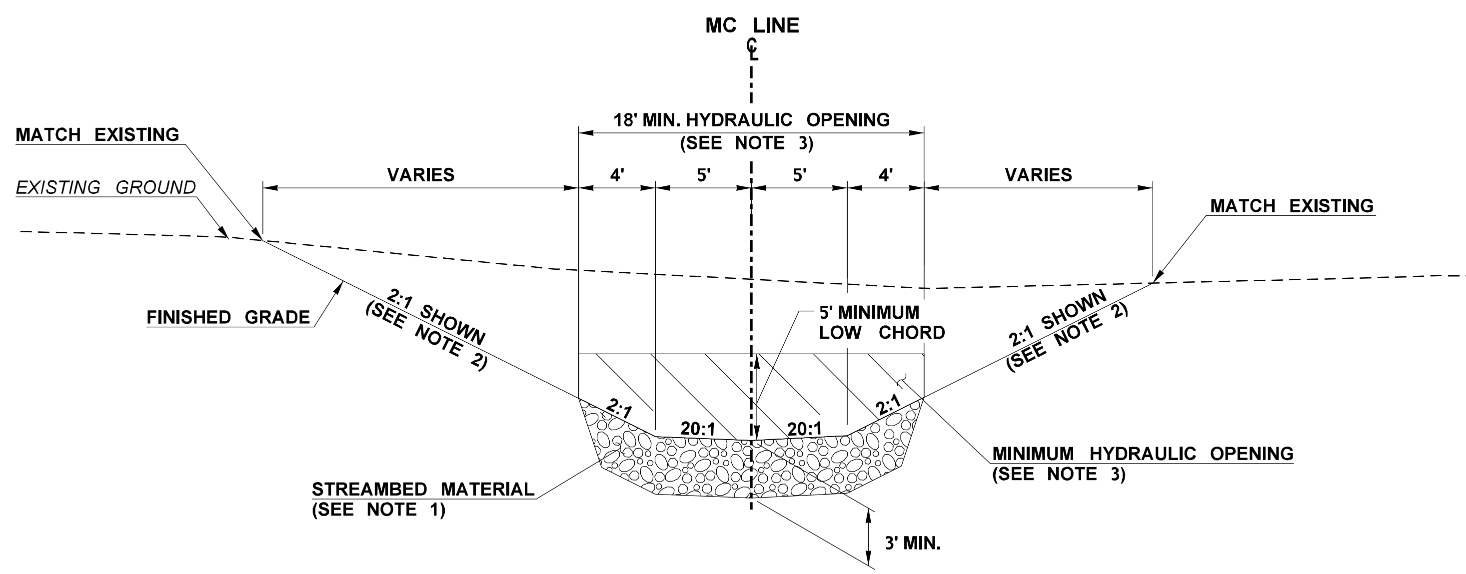
PLAN REF. NO. CP1

SHEET 3 OF 4 SHEETS



SECTION A

STATION
MC 2+83.50 TO 3+30.00
MC 4+07.00 TO 4+55.00



SECTION B

STATION
MC 3+30.00 TO 4+07.00

NOTES:

1. SEE SPECIAL PROVISIONS "AGGREGATE FOR STREAMS, RIVERS, AND WATERBODIES" FOR STREAMBED MATERIAL.
2. SLOPES SHOWN OUTSIDE HYDRAULIC OPENING ARE FOR ILLUSTRATIVE PURPOSES ONLY TO DEPICT ESTIMATED AREA OF POTENTIAL IMPACT. FINAL AREAS OF IMPACT TO BE DETERMINED PENDING GEOLOGICAL AND STRUCTURAL INVESTIGATION, STRUCTURE TYPE AND STRUCTURE LOCATION.
3. PROPOSED STRUCTURE SHALL NOT ENCROACH INTO MINIMUM OPENING SHOWN ON PLAN.

PRELIMINARY - NOT FOR CONSTRUCTION

pw:\\HQOLYMAPPW03P.WSDOT.LOC:WSDOT\Documents_HQ\Fish Passage\ORproj\108\8.89_McDonaldCreek\Hydraulics_CAD_Sheets\StreamPlanProfDetails\XL5950_DE_CD_001

FILE NAME	c:\pwworking\pw_wsdot\d0249846\XL5950_DE_CD_001.dgn
TIME	11:12:26 AM
DATE	7/12/2020
PLOTTED BY	CWILCOX
DESIGNED BY	S. BEVAN
ENTERED BY	C. WILCOX
CHECKED BY	J. HEILMAN
PROJ. ENGR.	J. METTLER
REGIONAL ADM.	J WYNANDS

REVISION	DATE	BY

REGION NO.	STATE	FED.AID PROJ.NO.
10	WASH	
JOB NUMBER XXXXX		
CONTRACT NO.		LOCATION NO. XL5950

DATE
P.E. STAMP BOX

DATE
P.E. STAMP BOX

Washington State Department of Transportation

HDR

SR 108
MP 8.89
McDONALD CREEK

STREAM DETAILS

PLAN REF NO CD1

SHEET 4 OF 4 SHEETS

Appendix C – WDFW Future Projections for Climate-Adapted Culvert Design Printout

Future Projections for Climate-Adapted Culvert Design

Project Name: 990278

Stream Name:

Drainage Area: 113 ac

Projected mean percent change in bankfull flow:

2040s: 15.8%

2080s: 21.4%

Projected mean percent change in bankfull width:

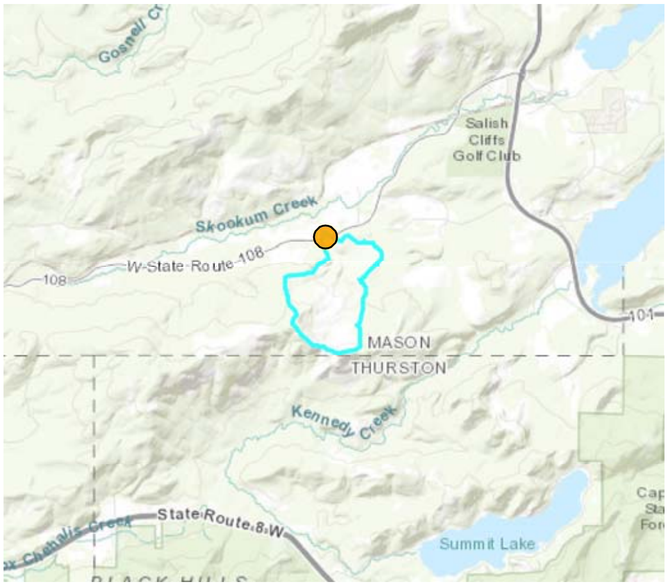
2040s: 7.6%

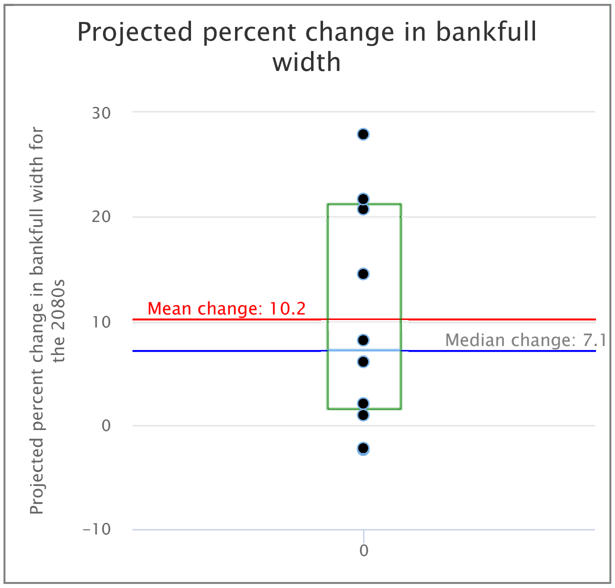
2080s: 10.2%

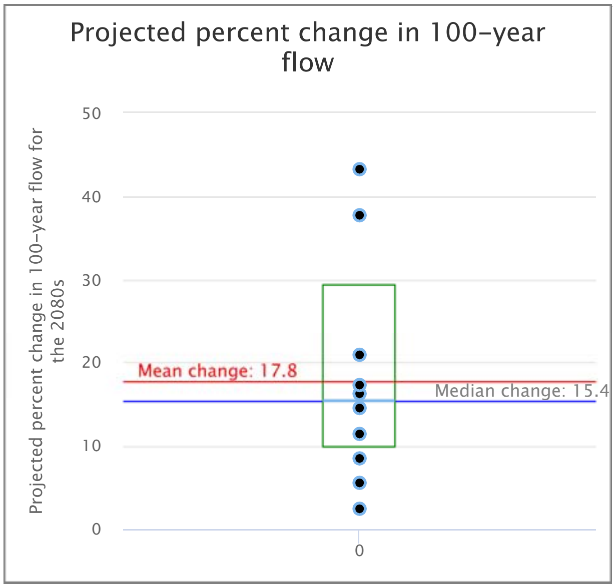
Projected mean percent change in 100-year flood:

2040s: 9.4%

2080s: 17.8%







Black dots are projections from 10 separate models